Aeromagnetic Solutions Incorporated

Analysis of NSWC Ocean EM Observatory test data: final report

J. Bradley Nelson

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14. ABSTRACT
NSWC-Carderock is leading a defense/academia group to instrument the South Florida Ocean Measurement Facility with a variety of undersea and on-shore sensors to determine if the electromagnetic fields generated by the ocean can be correlated with measurements of water flow, salinity, temperature, etc. Aeromagnetics Solutions Incorporated was awarded NICOP - N62909-15-1-2054 to help identify the sensors required, plan the sensor deployment, and analyze the initial data for quality assurance. This report contains ASI's analyses of the 11 data sets provided by NSWC, and summarizes the results and recommendations provided to NSWC regarding sensors, data acquisition systems, and deployment locations.

15. SUBJECT TERMS
magnetic anomaly detection (MAD), oceanographic magnetic fields, coherence, magnetic noise reduction

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Executive Summary

NSWC-Carderock Ft. Lauderdale Division is leading a defense/academia group to instrument the South Florida Ocean Measurement Facility (SFOMF) with a variety of undersea and on-shore sensors (contract N6554014D0008). The aim is to determine if the electromagnetic fields generated in the ocean [1] and in the air above the ocean, can be correlated with measurements of the oceanographic parameters such as water flow, salinity, temperature, etc. ONR is supporting this Ocean Observatory project by funding NRL Stennis to assist with the definition of instrumentation requirements. Aeromagnetics Solutions Incorporated was awarded NICOP - N62909-15-1-2054 in part to help identify the sensors required, plan the sensor deployment, and analyze the initial data for quality assurance.

This report documents the analyses of eleven (11) data sets that were provided by NSWC-Carderock Ft. Lauderdale Division to the authors. The sets included shorestation magnetic, undersea magnetic, and undersea acoustic doppler current profile (ADCP) sensor data. The shorestation and undersea magnetic hardware and data acquisition software were changed during the period of performance based on informal letter reports and recommendations provided by the authors to the NSWC personnel as each data set was analysed. This report summarizes the important conclusions and recommendations from each of the analyses, and the twenty (20) letter reports that the authors wrote are included as individual Appendices to this report.

The analysis and recommendations can be broken into the following topics:

1) shorestation and undersea magnetometer time-stamp issues
2) shorestation hardware issues
3) shorestation magnetic noise issues
4) undersea magnetic noise issues
5) identification and testing of an alternate shorestation location
6) calculation of coherence and geomagnetic noise reduction obtained at the alternate shorestation
7) changing from G823 to G824 magnetometers
8) ADCP data quality.

Each topic will be briefly described, including the problems encountered, recommendations provided, and solutions obtained. A table summarizing the status of each topic as of 31 March 2016 is provided at the end of the Executive Summary.

1. Shorestation and undersea magnetometer time-stamp issues: The original undersea magnetometer data acquisition software used Windows calls to the computer clock, with a resolution of only 0.1 seconds. The time resolution wasn't adequate so the program PUTTYLOG.exe was used instead. It still uses the computer's clock to time stamp the data, but the time resolution is 0.001 seconds. On some data sets the undersea magnetometer time stamp was in error because the GPS-based time server that was supposed to maintain synchronization of the computer's clock with UTC had failed. NSWC Ft. Lauderdale staff made that system more robust and data sets from late 2015 & 2016 did not have this problem.

Unfortunately the PUTTYLOG software wrote a time stamp, then the data, then repeated the same time stamp which was confusing. In March 2016 the undersea data acquisition software was changed to a

Labview program written at NSWC-Carderock. The time stamp resolution is still 0.001 seconds but the redundant time value is not written.

A Campbell-Scientific data logger is used for the shorestation magnetometer data recording system. Although the data is recorded in a proprietary format that must be converted before it can easily be read into MATLAB or IDL, it has not had any issues with time-stamping or missing data.

All issues with time-stamps on the undersea and shorestation data recording systems have now been resolved.

2. Shorestation hardware issues: The original G823 shorestation magnetometer became very noisy early in 2015. Analysis of the Feb 2015 data sets clearly showed that the sensor was failing and the authors recommended that it be returned to the manufacturer for repair. It was re-installed in the summer of 2015 and has not had any issues since.

All issues with the shorestation hardware have been resolved.

3. Shorestation magnetic noise issues: A great deal of effort was expended on this topic, including the analysis of several data sets from Nov 2014 through Nov 2015. There were three problems with overlapping symptoms. The first was the failing magnetometer mentioned in item 2. The second issue was that NSWC installed a solar powered charging station at the Westlake Park shorestation in August 2015 and the electrical charging currents generated fields at 0.5 Hz + harmonics. The charger had multiple charging modes that had to be investigated, and the effect of increasing the separation between the magnetometer and the charging had to be measured. It was found that increasing the separation from the initial 40 ft to 100 ft eliminated the 0.5 Hz + harmonics AC noise, but other environmental sources produced discrete lines at 0.1 Hz + harmonics. In addition there were many small, but real, magnetic transients which raised the average noise level to approximately 20 pT/√Hz which was much higher than the noise on the underwater magnetometer. Thus a simple subtraction of the shorestation from the undersea magnetometer data actually ADDED high-frequency noise. A frequency-domain noise cancelling approach was more successful than a simple subtraction of the Westlake basestation data, but it was still not ideal.

It was determined that an alternate location for the basestation would have to be identified and tested before the Ocean Observatory could become operational.

4. Undersea magnetometer noise issues: Because of the shorestation magnetic noise issues, it was difficult to determine if the undersea magnetometer was measuring real ocean-generated fields, or if it too had sensor noise problems. The authors recommended that NSWC collect data with and without the ADCP running to see if that had any effect on the undersea magnetometer noise level, and to record the actual electrical currents drawn from the power supplies in the Range building in both cases. There was no obvious difference in the undersea magnetometer noise levels with and without the ADCP running. There was definitely AC modulation on the electrical current drawn when the ADCP was running, but the frequencies of those modulations did not match any frequencies in the undersea magnetometer spectrum. Thus it was concluded that even though there appeared to be a "magnetic quiet time" during the night, and generally more magnetic noise during the day, it did not appear to be associated with any of the undersea hardware.

The undersea magnetometer is accurately measuring the magnetic fields in the water and there are no issues with undersea magnetometer noise.

5. Identification and testing of an alternate shorestation location: NSWC staff and the authors used Google Earth to identify potential isolated, but secure, locations where a magnetic shorestation could be set up. Several sites including unused and active airports were considered, but a better choice was deemed to be at the eastern edge of the Everglades directly west of Ft. Lauderdale. The chosen site was on top of a berm along a South Florida Water Management District canal. The gates are kept locked so it is a fairly secure site, and NSWC already had a key to the gates from previous testing conducted by NSWC Carderock in 2011.

Tests were conducted at the site in March 2016 and the magnetic noise level was found to be considerably lower than the Westlake Park site.

6. Calculation of coherence and geomagnetic noise reduction obtained: A short data set was collected in March 2016 that included undersea magnetometer data, basestation magnetic data from the Westlake Park site, and basestation magnetic data from the Everglades site. Even though it was some 28 miles from the undersea magnetometer location vs. only 8 from the Westlake Park basestation to the undersea magnetometer location, both the coherence and geomagnetic noise cancellation achieved using the Everglades basestation were superior to that achieved using the Westlake Park basestation.

Unless some unforeseen issue arises, the basestation will be setup permanently at the Everglades location.

7. Changing from G823-G824 magnetometers: NSWC intends to replace the G823 magnetometers sampling at 10 Hz to G824 magnetometers (10 x less noise) sampling at 125 Hz. This will be done for both the undersea and shorestation sites. The undersea data may be filtered and sub-sampled for recording, but using a higher sampling rate will eliminate any problems with aliasing noise from higher frequencies. This may require a modification to the Labview data recording software for the undersea magnetometer. Because the shorestation data recording is done on the Campbell data logger, it may also have to be adjusted to match the modified sample rate.

NSWC has already begun designing the undersea and shorestation recording systems to accept the G824 sensors, supply increased power, etc. These G824's have been used extensively and successfully during the shorestation tests. For this reason, the authors have chosen to publish this document at this time instead of waiting for (potentially) several months until both the shorestation and undersea magnetic sensors have been swapped.

The authors foresee no issues with swapping the G823 sensors for G824s beyond the engineering concerns that NSWC is already addressing.

8. ADCP data quality: Two data sets were analysed and no problems were identified. There were no missing data, the time-stamps were fine, and the data quality was very good.

The only issue was that the ADCP was set up to record 75 bins of usable data in a water depth of 264 meters, with the uppermost bin at 31.68 meters below the water surface. Thus the ADCP's do not record surface water motion.

1. Introduction

NSWC-Carderock Ft. Lauderdale Division is leading a defense/academia group to instrument the South Florida Ocean Measurement Facility (SFOMF) with a variety of undersea and on-shore sensors (contract N6554014D0008). The aim is to determine if the electromagnetic fields generated in the ocean [1] and in the air above the ocean, can be correlated with measurements of the oceanographic parameters such as water flow, salinity, temperature, etc. ONR is supporting this Ocean Observatory project by funding NRL Stennis to assist with the definition of instrumentation requirements. Aeromagnetics Solutions Incorporated was awarded NICOP - N62909-15-1-2054 in part to help identify the sensors required, plan the sensor deployment, and analyze the initial data for quality assurance.

The work done can into the following topics:

1) shorestation and undersea magnetometer time-stamp issues
2) shorestation hardware issues
3) shorestation magnetic noise issues
4) undersea magnetic noise issues
5) identification and testing of an alternate shorestation location
6) calculation of coherence and geomagnetic noise reduction obtained at the alternate shorestation
7) changing from G823 to G824 magnetometers
8) ADCP data quality.

This report documents the analysis performed and the recommendations that Aeromagnetic Solutions Incorporated and NRL Stennis have already provided to the Ocean Observatory program as informal letter reports. The twenty individual letter reports are contained in Appendices A-T.

Table 1 contains a description of the sensors involved. Figure 1 shows the locations of the various sensors as envisioned during the project kick-off meeting at Florida Atlantic University in July 2015.

Table 1. Sensors used in the Ocean Observatory project.

Sensor type	Manufacturer	Sample Rate	Location	Comment
G823 magnetometer	Geometrics	10 Hz	On-shore	Repaired after Feb 2015. May be replaced with G824 in final installation
G823 magnetometer	Geometrics	10 Hz	Sea-bottom	259 m depth; will be replaced with G824 in final installation
WorkHorse Broadband ADCP	Teledyne	1 profile every 61.32 s	Sea-bottom	~ 10 m from G823
Pressure sensor Series 8000	Paroscientific Inc.	unknown	Sea-bottom	260-275 m water depth
Trillium Compact Seismometer	Nanometrics	1000 Hz	Sea-bottom	260-275 m water depth
Long-baseline E-field (LLEFA)	NSWC	1000 Hz	Sea-bottom	260-275 m water depth
Short-baseline Tria-axial E-field	NSWC	1000 Hz	Sea-bottom	260-275 m water depth

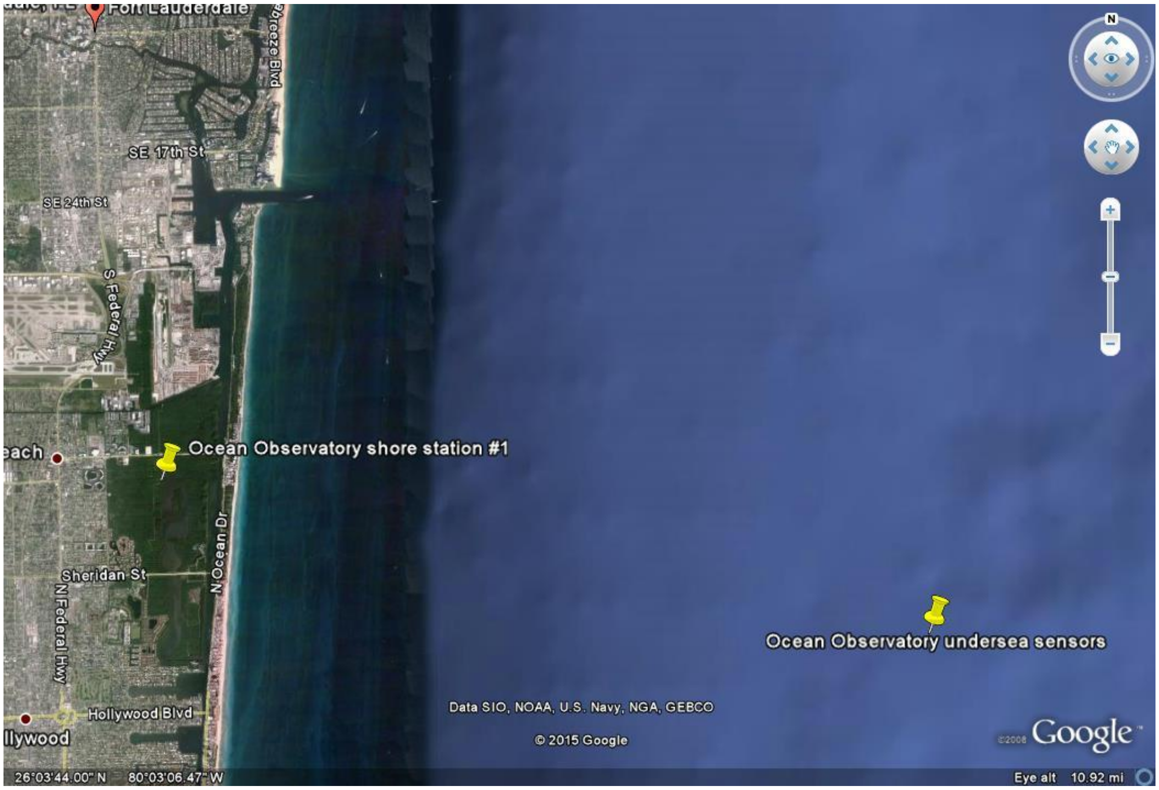


Figure 1. Locations of sensors used in the Ocean Observatory project.

Of these sensors, Aeromagnetics Solutions Incorporated was asked to focus on the G823 and G824 magnetometers to ensure that their data were of adequate quality, and to perform a quick-look of the ADCP signals to verify data quality. Consequently this report focuses on only the magnetometer and ADCP data from several tests.

Figure 2 shows the G823 and ADCP sensors that were deployed on the sea-bed where the water depth was 259 m.

NSWC Carderock – Ft. Lauderdale Division staff have written an operations manual for the shore station which contains information necessary to assemble, test, and operate the reference station and its subsystems. The magnetic observatory shore reference station consists of a G823 or G824 Cesium magnetometer, a Campbell Scientific Inc. data logger, and a solar charging station. The system is controlled by a remote operating station and is programmed in CRBasic. A full description is given in [2]. Figure 3 shows the G823 magnetometer [3] and shore station electronics. For the final installation, the G823 magnetometers may be changed to G824 magnetometers because their noise level is approximately 10 x lower. However, the housings shown in Figures 2 and 3 will remain similar except for the internal mounting bracket.

Figure 2. G823 and ADCP sensors mounted on individual "baskets" that were deployed on the sea-bottom. The separation of the baskets was ~ 10 m.

Figure 3. G823 magnetometer and the shore station electronics/solar charging station.

2. Description of data sets used in the analyses

The shore station magnetic data sets were collected using a Campbell Scientific Inc. data logger that records the data in a proprietary format. The program *FileFormatConvert.exe*, also supplied by Campbell Scientific Inc., was used to convert the files into ASCII. The undersea magnetic data was first collected using REALTERM.EXE on a dedicated computer at the Range facility, in later tests using PUTTYLOG.EXE, and finally in March 2016 using an NSWC-Carderock interface written in Labview. The data were displayed and analysed using IDL procedures written by the authors.

The ADCP data sets were collected using *PC200W_4.3.exe* and the files recorded in a binary format. The program *WinADCP.exe* was used to convert them into ASCII. The ASCII files were displayed and analysed in IDL using the procedures written by Will Avera of NRL Stennis.

Table 2 contains the filenames and descriptions of the data sets analysed.

Table 2. Filenames and descriptions of data sets analysed along with Section of the report and Appendix where the analysis is described.

Date	Sensors	Filename	Purpose of test	Section	Appendix
15 Nov 2014	shore G823 undersea G823	TOA5_56936_MagData_45_2014_11_15_0000.txt 20141115_MAG_LOG	Use to determine time alignment, shore and undersea noise levels, etc. The undersea magnetic data were recorded using REALTERM.EXE	3.1	A
11 Feb 2015	undersea G823	20150211-Pugsley-MagLog.txt	Determine if PUTTYLOG.EXE provides improved time-tags vs. REALTERM.EXE. Also check for noise level on undersea magnetic sensor.	3.2	B
12 Feb 2015	shore G823	TOA5_56936_MagData_139.txt	Determine if the noise level on the shore station had changed since the Nov 2014 test	3.3	C
15-28 Aug 2015	shore G823	TOA5_56936_MagData_21.dat (ON-OFF) TOA5_56936_MagData_17.dat (PWM)	Determine if ON-OFF or pulse-width modulation solar re-charging system affects magnetic noise on shore station	3.4	G
3-7 Sept 2015	shore G823 undersea G823	TOA5_56936_MagData_31.dat TOA5_56936_MagData_32.dat TOA5_56936_MagData_33.dat TOA5_56936_MagData_34.dat 20150903_MAG_LOG_UTC.txt	Determine time alignment, shore and undersea noise levels, etc.	3.5	D,E,F
5 Jan 2015	shore G823	TOA5_56936_MagData_100_2015_01_05_0000.dat	Use to compare noise at shore station in Jan 2015 vs. that in Sept 2015.		F
20-27 Oct 2015	shore G823 undersea G823	TOA5_56936_ MagData _87.dat TOA5_56936_ MagData _88.dat TOA5_56936_ MagData _89.dat TOA5_56936_ MagData _90.dat TOA5_56936_ MagData _91.dat TOA5_56936_ MagData _92.dat 20151022 MagLogAppend.log	Check if noise on shore station magnetometer is due to solar charging unit. Also check to see if portions of it are due to environmental sources Determine if ADCP power causes noise on undersea magnetometer		H,I,J L

	current sensor on shore	20151020_ADCP_Mag_Current_Fs-5k.csv 20151020_Mag_Only_Current_Fs-5k.csv			
17-18 Nov 2015	Shore G823 G824	TOA5_56936_MagData_119.dat TOA5_56936_MagData_120.dat com9-20151117161805.log	Determine if shorestation noise is seen on a different sensor at a different sample rate		K,M,N
14-17 Mar 2016	Shore G823 G824; shore G823 undersea G823	TOA5_56936_MagData_96.dat TOA5_56936_MagData_97.dat Mar 17 2016 everglades.txt TOA5_56936_MagData_99.dat 20160315 - Node 1 Mag.txt	Compare noise from charging station at 40 ft vs. 100 ft Compare basestations in the Everglades vs. Westlake Park for coherence & noise reduction vs. the undersea magnetometer		O,P,Q,R
19-23 Mar 2015	ADCP	20150319_ADCP_LOG_UTC.txt	Check for ADCP errors		S
3-7 Sept 2015	ADCP	20150903_ADCP_LOG_UTC.txt	Check ADCP data for errors.		T

3. Analysis of magnetic data

3.1 15 Nov 2014 (shore station and undersea)

The purpose of this test was to check the time-alignment of the undersea and shore station magnetic recording systems and to determine if REALTERM.EXE was adequate for recording the undersea data. Secondary goals were to determine what the noise levels were on both the undersea and shore station magnetometers and to estimate the noise reduction possible using time-domain and frequency-domain cancellation algorithms. The informal letter report is included in Appendix A. The main conclusions were:

1) The timestamp on the shore station data was UTC as required for the Ocean Observatory project. However, the timestamp on the undersea magnetic data was inadequate. The REALTERM.EXE software used the data acquisition computer's time when the serial data arrived so the time on that computer must be set to UTC and periodically updated (once an hour if possible) to match the shore station time. This was not happening during the 15 Nov 2015 data collection. In addition, the resolution on the time-stamp using REALTERM.EXE was only 0.1 seconds which is not fine enough for a sample rate of 10 Hz. Thus the undersea magnetic data must be recorded with different software than was used for the 15 Nov 2015 data set.

2) The shore station magnetometer had single-point spikes and periods of excess noise compared to previous trials as shown in Figure 4. It was recommended the sensor alignment be verified, and the sensor be checked by comparing the signals from two G823 magnetometers at the shore station location. If the excess noise is seen on both sensors, then it is man-made noise, not a failing sensor that is the problem. In this case, another shore station location should be found. If this is not the case, then the failing sensor should be replaced.

3) There were also man-made anomalies in the shore station data that had to be removed manually before the data could be used for geomagnetic noise reduction. This suggested that the shore station location might not meet the requirements for the Ocean Observatory project.

4) The undersea magnetic data have no excess spikes, but they clearly show an attenuation of the geomagnetic signals due to the skin-depth of seawater. The equation

$$PSD' = PSD * \exp(-2z/\delta)$$

where z is the sensor depth and δ is the skin depth = 250.0/√(Frequency in Hz) was used to create Figure 5. If the shore station magnetic data are to be used for geomagnetic noise reduction, then either the attenuation must be calculated and accounted for in any time-domain subtraction method, or a frequency-domain cancellation (FDC) method of noise cancellation can be used.

5) The undersea data contain ship signatures and one must be careful not to include those signatures when calculating the transfer functions for the FDC method.

6) There was no obvious problem with coiling the G823 cable or running the electronics close to the sensing head in the undersea installation. Similar sensor housing and cabling methods should also work with the G824 magnetometers.

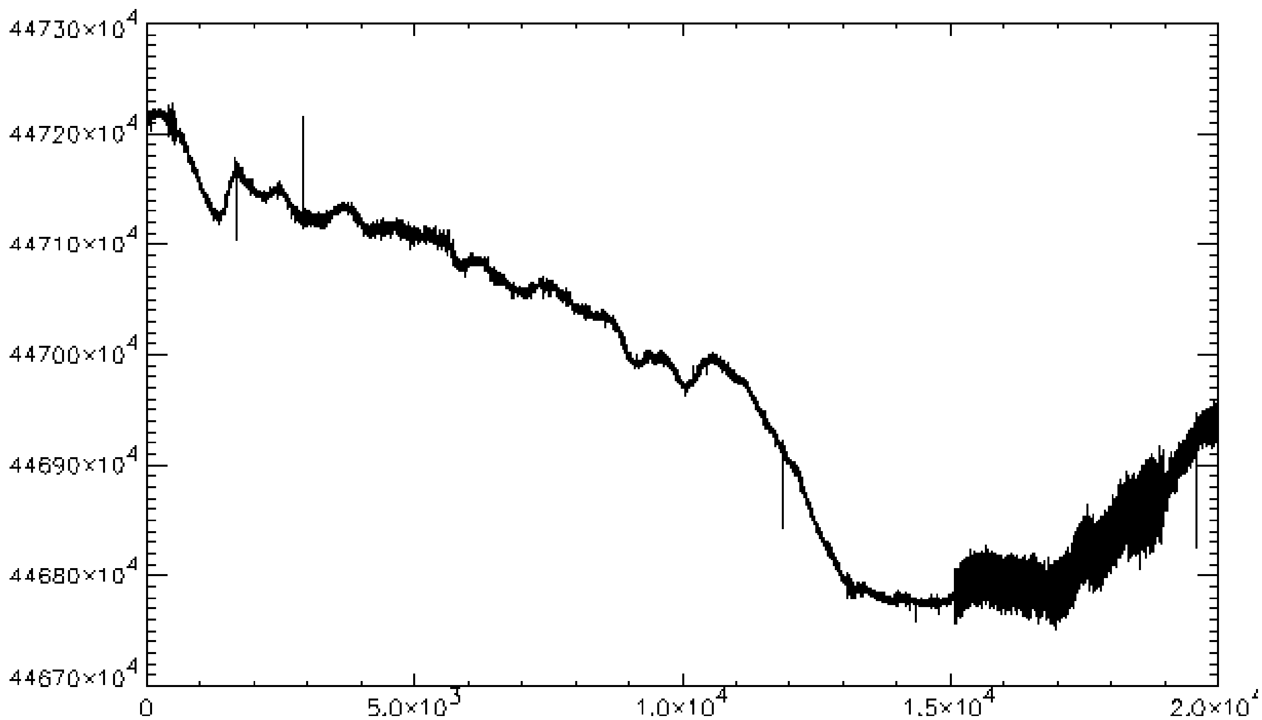


Figure 4. Magnetic field measured at the shore station showing single-point spikes (1800, 200, 11800, and 19500 seconds) and periods of increased noise (15000-20000 seconds).

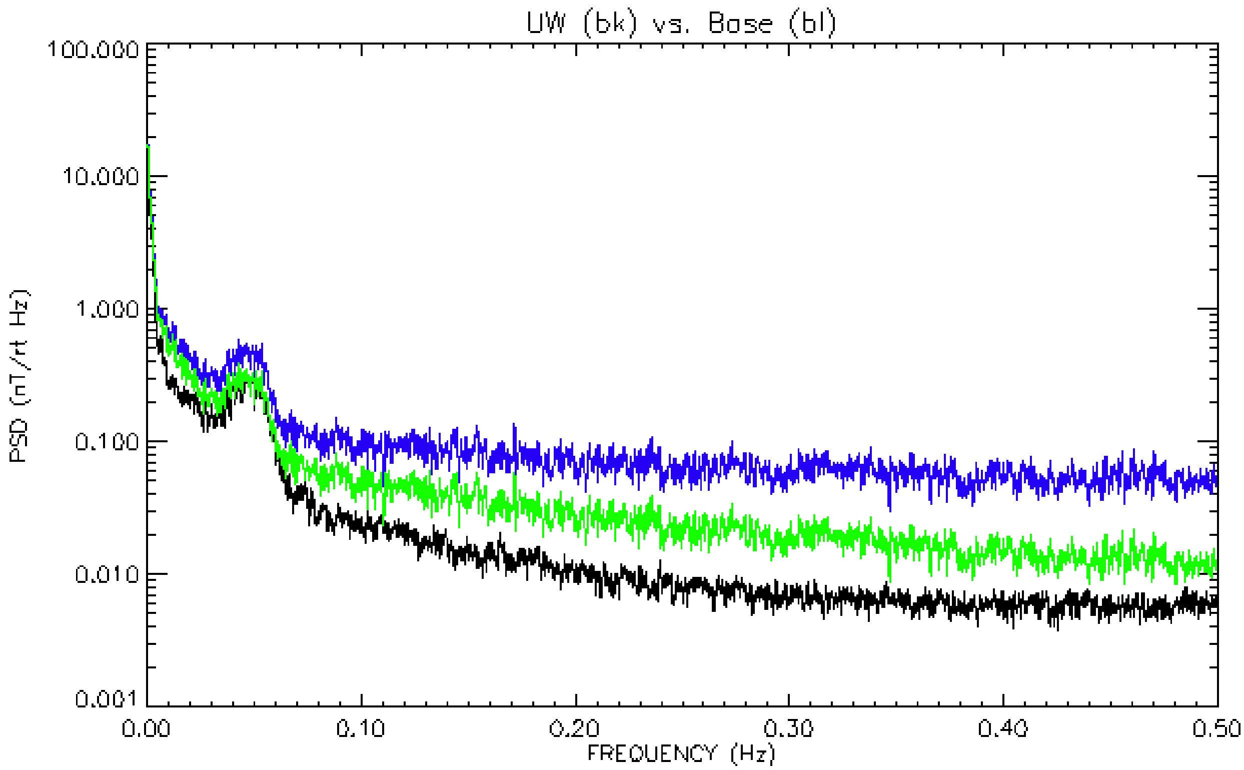


Figure 5. PSD of magnetic fields from the undersea sensor (black), shore station (blue) and shore station corrected for skin depth attenuation to depth of the undersea sensor = 259 meters (gr). Geomagnetic signals are evident in the band from 0.03-0.06 Hz.

3.2 11 Feb 2015 (undersea)

The purpose of this test was to determine if PUTTYLOG.EXE software provided improved time-tags vs. simply using REALTERM.EXE to record the undersea magnetic data. The secondary goal was to measure the noise level on undersea magnetic sensor with this hardware/software configuration. The informal letter report is included in Appendix B. The main conclusions were:

1) The PUTTYLOG.EXE time-stamping software did not miss any data points, but there are places where the time-stamp did not update. These were most likely caused by a data transmission failure when the mouse on the data acquisition computer was being moved and should not cause any problems for automated data collection. Thus the PUTTYLOG.EXE time-stamping software should be used in the Ocean Observatory project to record the undersea magnetometer data.

2) The Power Spectral Density of the undersea magnetic data (when no ship signatures were present), reached a minimum of ~ 2 pT/√Hz near 0.5 Hz and rises to ~ 10 pT/√Hz near 5 Hz. (see Figure 6) This is essentially the same as the G823 sensor noise. This implies that the G823 installation is adequate for the Ocean Observatory project. However, it should be noted that there was no ADCP operating in the vicinity of the G823 magnetometer and thus it is not a test of the total undersea installation.

3) There are very small discrete lines near 0.2 and 0.3 Hz – suggesting the fundamental is actually 0.1 Hz but it is lower than the ambient field variations so it is not visible. However, these lines are very small and should not cause any problems with analysis of the Ocean Observatory project data.

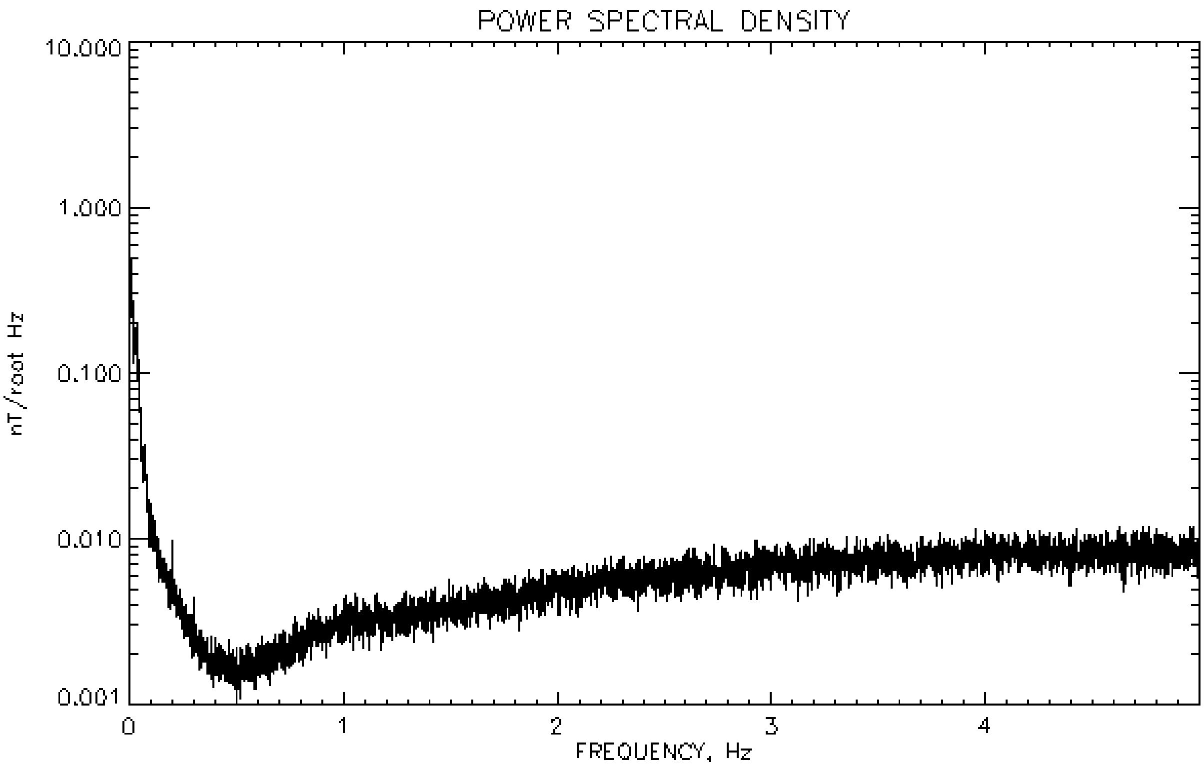


Figure 6. Power Spectral Density (PSD) of the undersea magnetic data collected on Feb 11, 2015. The data points used to calculate the PSD did not include any ship signatures.

3.3 12 Feb 2015 (shore station)

The purpose of this test was to measure the magnetic noise level at the shore station to determine if it had changed since the Nov 2014 test (see section 3.1). The informal letter is included in Appendix C. The main conclusions were:

1) The noise level was ~ 20 pT/√Hz (see Figure 7), which is about 20 x the sensor noise level. There were also discrete frequencies and either a resonance, or a moving line as was seen in the Nov 2014 data.

2) The magnetometer was most likely failing as this behaviour is not normal. It was recommended that the G823 be returned to Geometrics for repair.

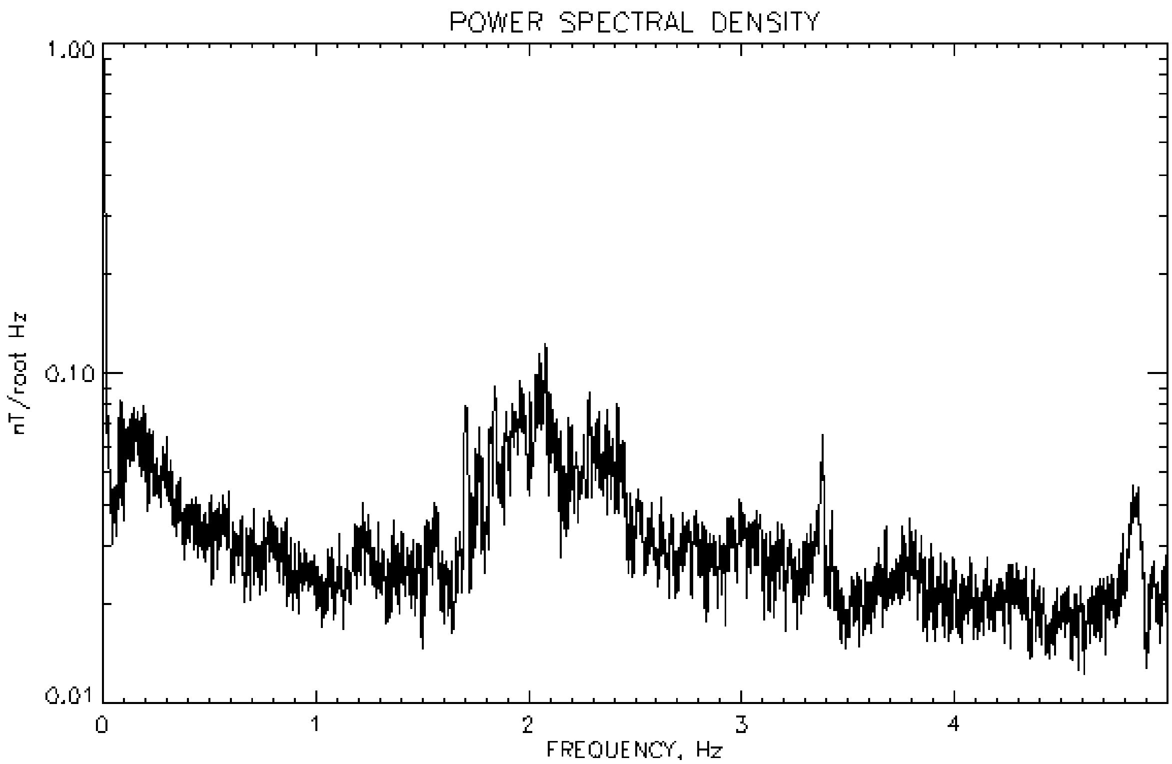


Figure 7. PSD of magnetic data collected at the shore station on Feb 12, 2015. Note the dramatically larger noise level, and very different spectral shape than what was measured on the undersea sensor on Feb 11 (shown in Figure 6).

3.4 3-7 Sept 2015 (shore station and undersea)

The main objective of this analysis was to determine the time alignment between the shore and undersea data acquisition systems, measure the magnetic noise levels on both sensors, and to make recommendations for any modifications required to the magnetic data acquisition systems. The secondary objective was to check ADCP data for errors and to do a quick-look comparison of the ADCP and magnetic data. The informal letter reports are contained in Appendices D and E. The main conclusions were:

1) Extra headers and the lack of LF CR at the end of each line in the undersea magnetic data made it difficult to read into IDL. This was corrected using an ASCII editor but it would be much better to change the format of the recorded data.

2) The undersea data contained many smaller glitches that had to be corrected by hand. It also contained many features with amplitudes of ~ 0.1 to 0.2 nT, with a duration of 10-20 seconds. (see Figure 8) These features did not correlate with the on-shore magnetic data. While it is possible that there are in fact oceanographic signals, the fact that a spectrograms of the undersea magnetic data for 4 consecutive days show a sharp “turn-off” of the features near 20,000 seconds after midnight UTC followed by a sharp “turn-on” of the noise near 32,000 seconds after midnight UTC. (see Figures 9a-d) The source of this noise is not understood but it will interfere with the utility of the Ocean Observatory project if it is not eliminated.

3) Two further tests were agreed to in discussions with the project team at NSWC. These were to run the undersea magnetometer with the ADCP turned off, and to run the undersea magnetometer with the ADCP turned on but recording the electric current draw from the power supply in the range facility.

4) Both the undersea and shore station magnetic data sets contained a few large-amplitude, short-duration transients in the Sept 7 data set (Figure 10), but they were not seen in the Sept 4, 5, or 6 data. These transients were always offset of 3.3 seconds in the two data sets, suggesting that one of the time-stamps was incorrect. Discussions with NSWC project staff indicated that the most likely cause of the discrepancy is that the undersea data recording computer was not receiving a proper time synchronization signal from the time server, which is the same problem that was identified in several of the earlier tests. They agreed to address this hardware problem before performing any additional data collections.

5) These large transients had a different shape in the air and in the water (Figure 11), but the rise time on the undersea signal was still so fast that it seems unlikely that it could be an external field penetrating 259 m of sea-water. The source of these large transients is unknown, but the one possibility is lightning strikes into the water. Weather records did indicate that it rained at the Ft. Lauderdale airport that day, but no lightning strike data for that day/location has been found to test the hypothesis.

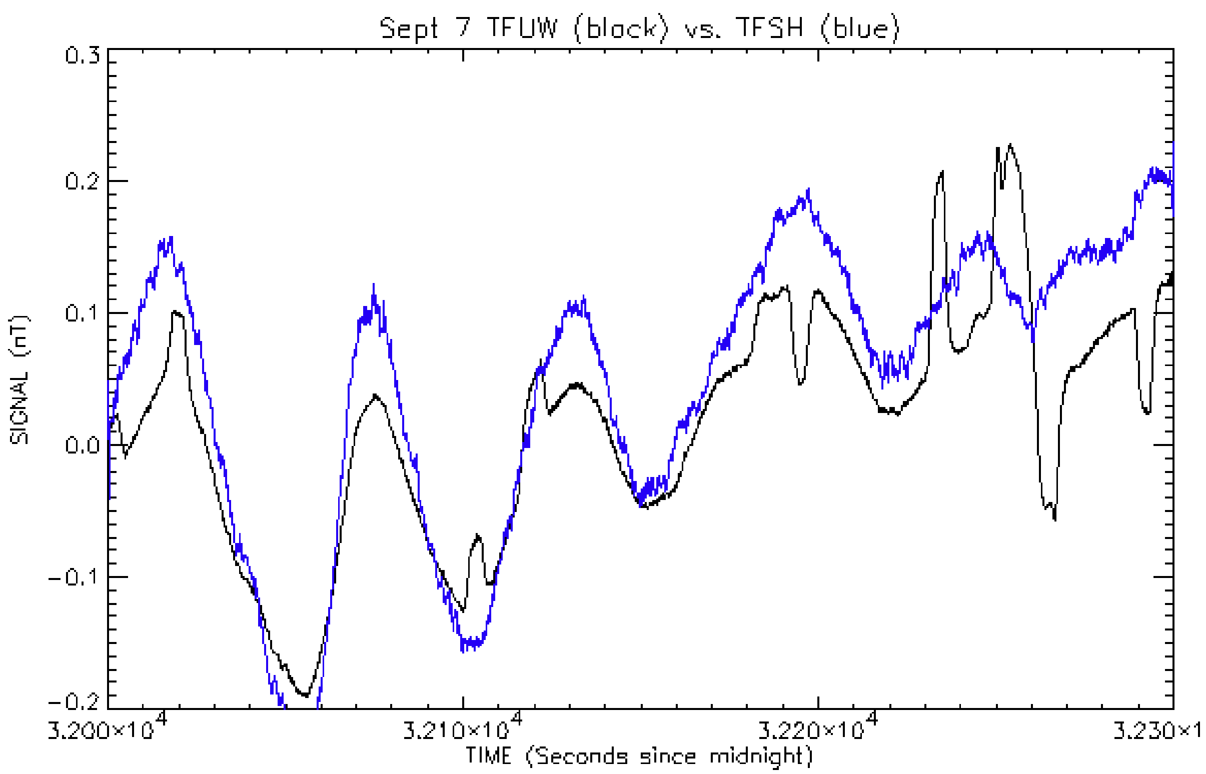
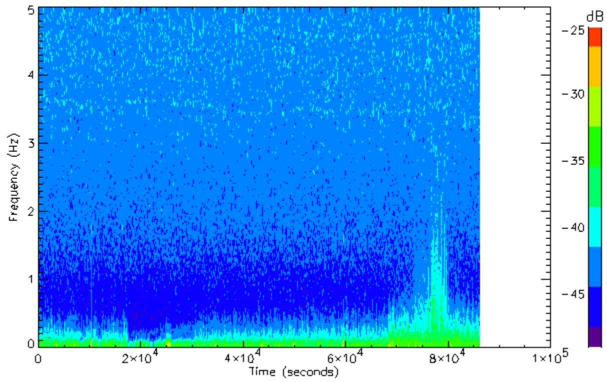
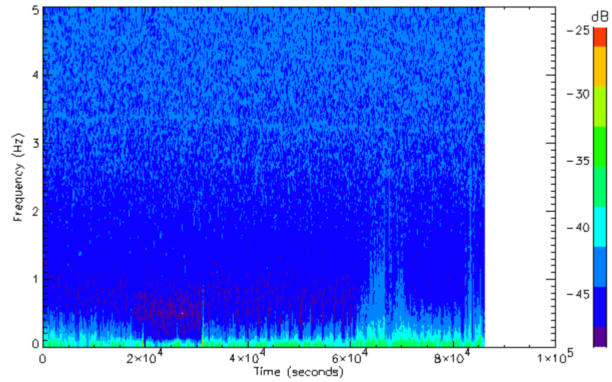


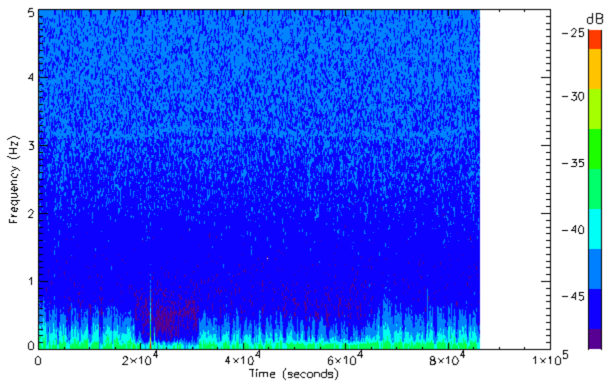
Figure 8. Noise features seen on the Sept 2015 undersea magnetic data (black) with amplitudes of ~ 0.1 to 0.2 nT and durations of 10-20 seconds vs. shore-station magnetic field (blue).



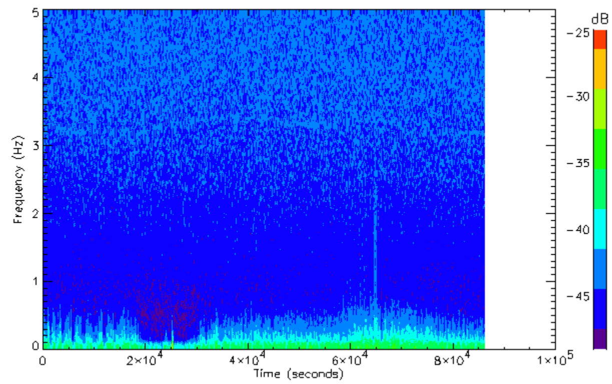
a = Sept 4



b = Sept 5



c = Sept 6



d = Sept 7

Figure 9a-d. Spectrograms of undersea magnetic field measurements for Sept 4-7 2015.

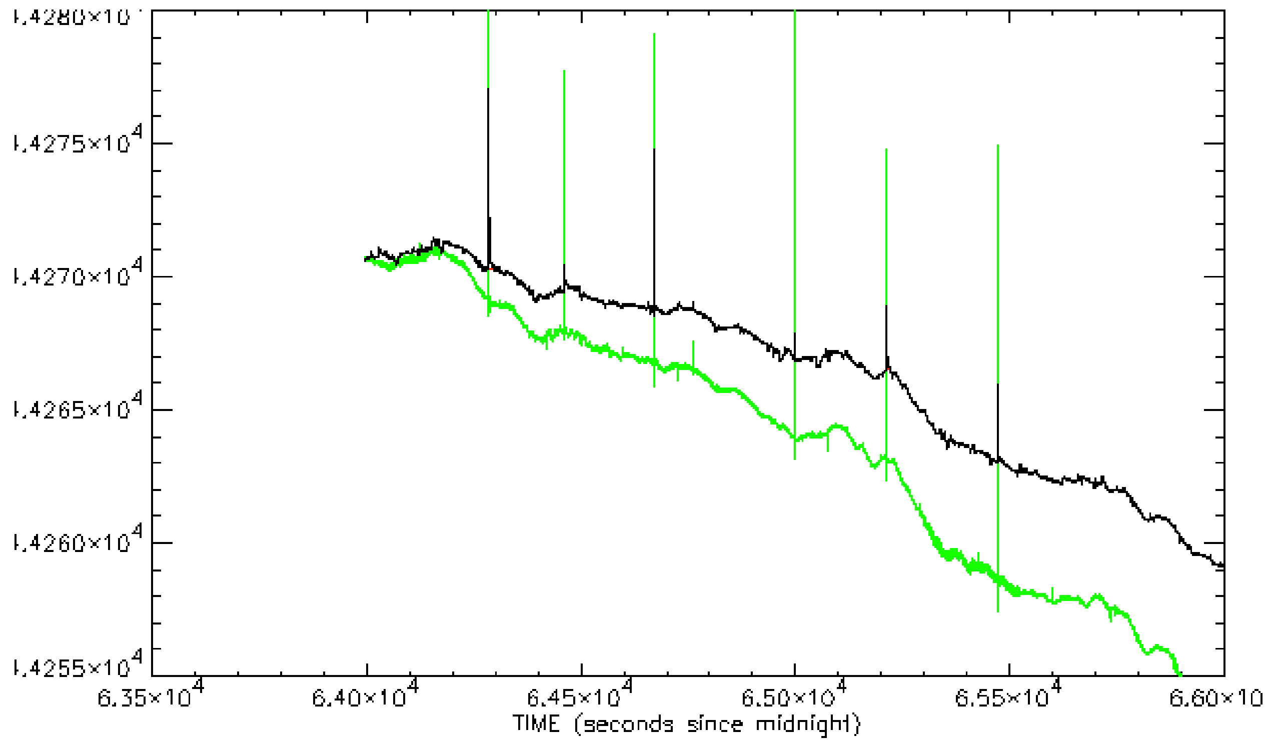


Figure 10. Large-amplitude, short-duration transients seen in Sept 7 2015 data in both undersea (black) and shore station (green) magnetic data.

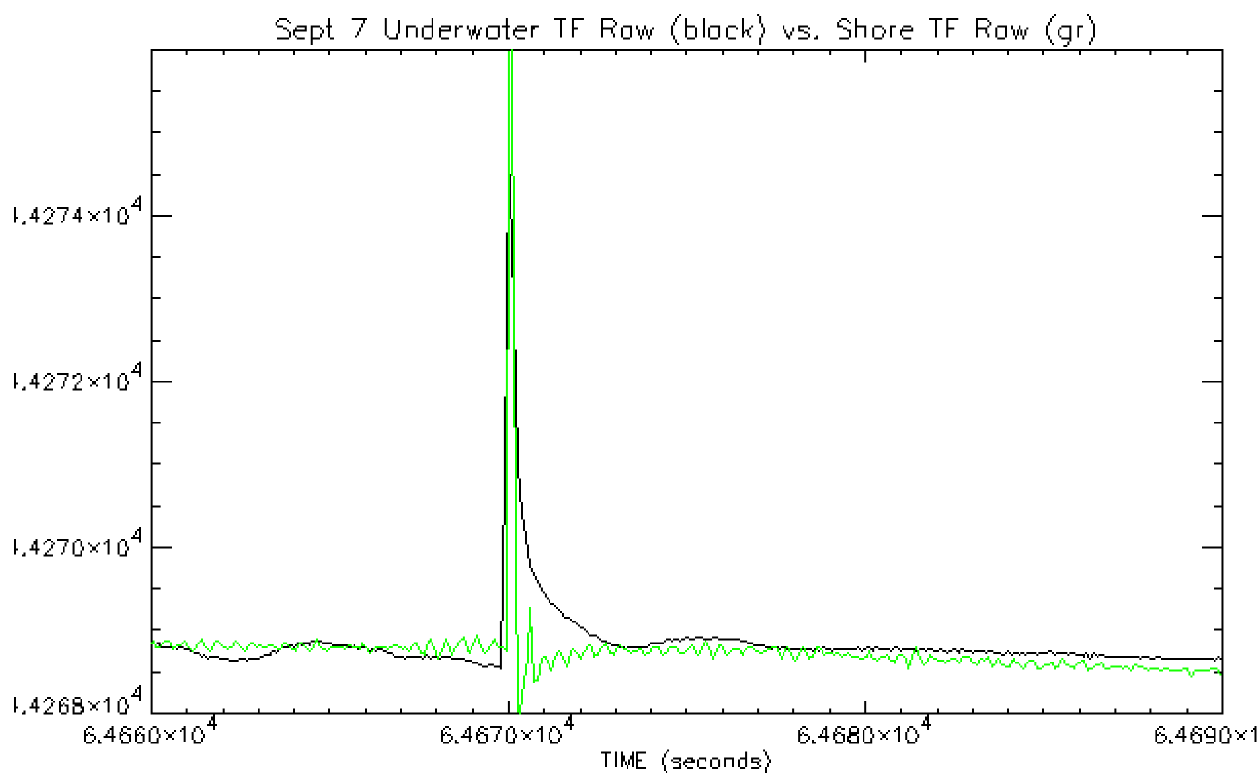


Figure 11. Large-amplitude, short-duration transient see in Sept 7 2015 data in undersea (black) and shore station (green) magnetic data. Note the very sharp rise time and different shape in each data set.

3.5 Jan 2015 vs. Sept 4-7 2015 (shore station)

The purpose of this analysis was to compare the noise levels of the shore station magnetic data to determine if the environment had changed significantly over the nine month period between the measurements. The informal letter report is given in Appendix F. Figure 12 shows the spectrograms of the magnetic data collected at the shore station on January 5, Sept 4, Sept 5, and Sept 7 2015.

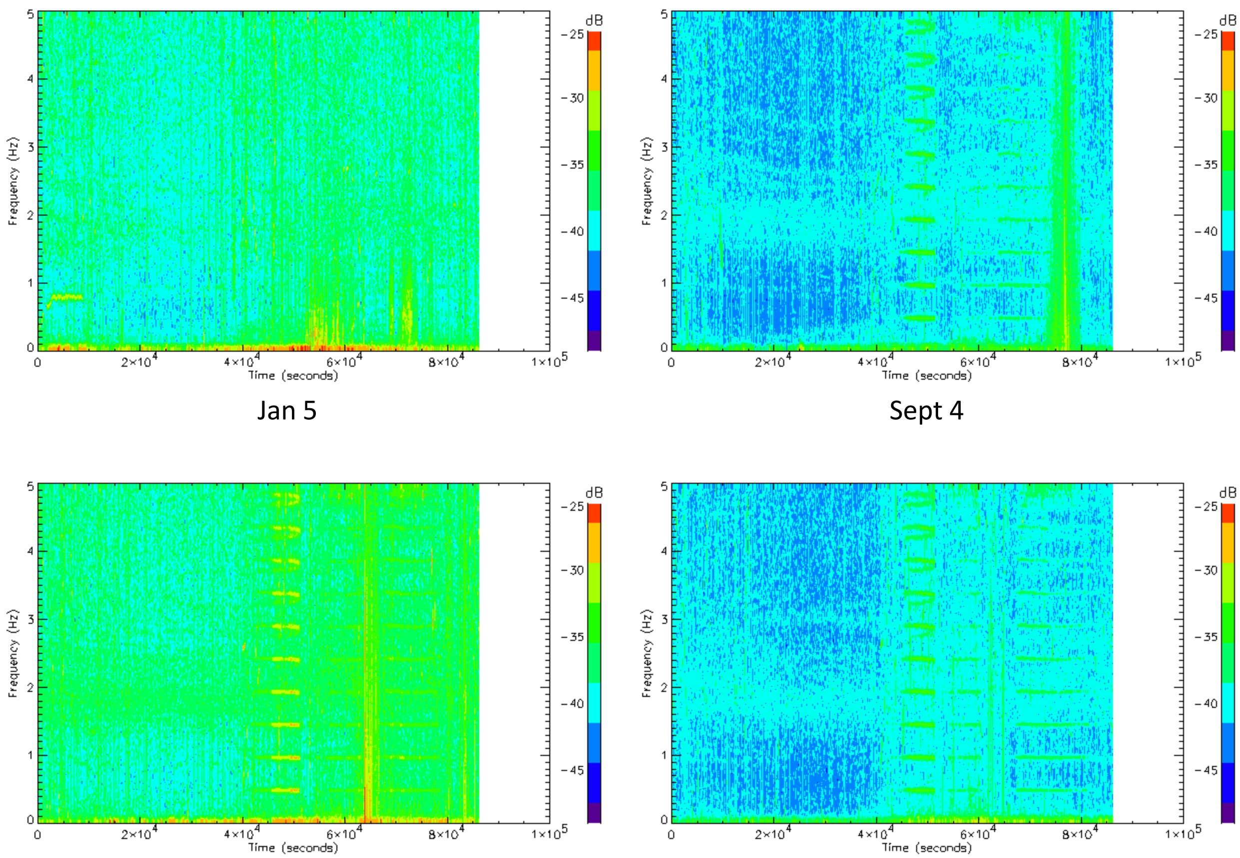


Figure 12. Spectrograms of magnetic field measured at the shore station on Jan 5, Sept 4, 5, & 7.

<u>Conclusion:</u>

There is a harmonic source that comes on around 45000 seconds ~ 12:30:00 UTC each day of the Sept 2015 data, but it is not present in the Jan 2015 data. Two possibilities were suggested:

a) the Ft. Lauderdale airport south runway was completed earlier in 2015 and the end of the runway is only 2 km from the shore station. It is possible that there is a beacon that pulses and creates the harmonic noise.

b) the solar charger was added to the basestation equipment in August 2015. It is very possible that the 0.5 Hz + harmonic noise seen in the Sept data is simply the magnetic field generated by the electrical currents associated with the charging circuit. It was recommended that NSWC provide Aeromagnetic Solutions Incorporated with data sets where the charging cycle was "ON/OFF" and "Pulse Width Modulated" to determine if the charging method affects the harmonic noise.

3.6 15-28 Aug 2015 (shore station)

The purpose of this analysis was to determine if the 0.5 Hz + harmonic noise seen in the September 2015 data sets was due to different types of charging cycles on the solar charging unit as per recommendation (b) in Section 3.5. The informal letter report is contained in Appendix G. The conclusion was that the harmonic noise began at the same time each day and had the same amplitude and frequency regardless of whether the charging cycle was "ON/OFF" or with "Pulse Width Modulation"

It was recommended that:

a) the NSWC collect a few days of data without the charging system running in order to determine if the harmonic noise is actually caused by the charging system, or if it is really due to a changing magnetic environment at the shore station.

3.7 20-27 Oct 2015 (shore station and undersea)

The main goal of this analysis was to determine if the 0.5 Hz + harmonics noise seen in the Westlake shorestation data was due to the solar charging system as per recommendation (a) in Section 3.6. The secondary goals were to check the overall quality of the undersea and basestation data, check the noise reduction obtained using a frequency-domain cancellation method, and determine how long the shorestation will operate on batteries without the charger. The informal letter reports are contained in Appendices H, I, J, and L.

The main conclusions were:

1) When the solar charger was not connected, the 0.5 Hz + harmonics noise was not present so those lines are definitely due to the solar charger. (see Figure 13). It was recommended that

   1a) NSWC make a 100 ft long sensor cable so the magnetometer can be moved further than 40 ft from the charging station. This will allow us to determine how far the magnetometer must be from the charger to avoid the 0.5 Hz + harmonics noise.

2) there was a 1 second difference between the undersea and onshore timestamps. Although it was easily corrected, a more robust system that automatically keeps the data acquisition system connected to the server time will be required for the Ocean Observatory

3) the skin-depth effect reduced the amplitude of the geomagnetic variations at the undersea magnetometer. This resulted in very poor geomagnetic noise reduction if only a simple subtraction of the onshore magnetic signal was used. However, the frequency-domain cancellation method takes account of the skin-depth effect so the geomagnetic noise cancellation was significantly better using this technique than with simple subtraction.

4) The coherence between the undersea and onshore magnetometer signals is > 0.9 for frequencies < 0.02 Hz. However, there is a secondary bump in the coherence around 0.06 Hz where there was a significant amount of geomagnetic activity (P3c pulsations?). This activity can be seen in the time series of the first plot and in the PSD plots.

5) The data collection system will remain operating without recharging for almost 96 hours.

6) However, there was significant noise near 1 Hz even when the charger wasn't operating (see Figure 14). It was recommended that NSWC do the following tests to determine whether the problem is due to G823 sensor or electronics overheating, or whether the magnetic noise is from the environment local to the chosen shore station:

6a) collect magnetic data with a G824 magnetometer running at high sampling rates to determine if the noise is from the environment, and whether the noise is really at the low frequencies seen in the G823 data or if it is being aliased from higher frequencies. If it is environmental, but it is being aliased from higher frequencies, then the problem might be solved by changing the shore station magnetometer to a G824. This would also involve changing the data collection software to filter and sub-sample the data prior to recording.

6b) remove the G823 sensor and electronics from the PVC enclosure, allow them to cool, and run them outside the enclosure for 2 days.

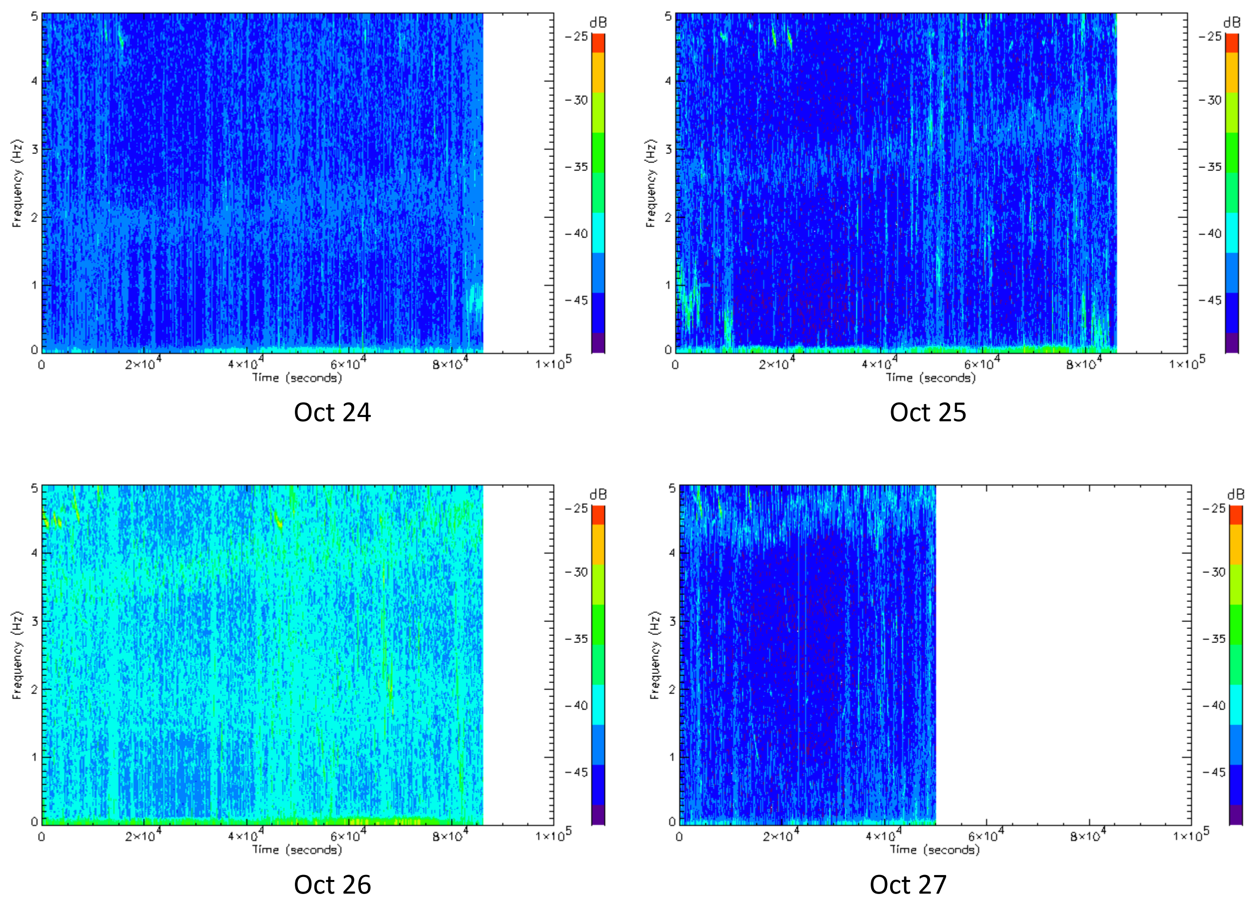


Figure 13. Spectrograms of magnetic field measured at the shore station on Oct 24-27.

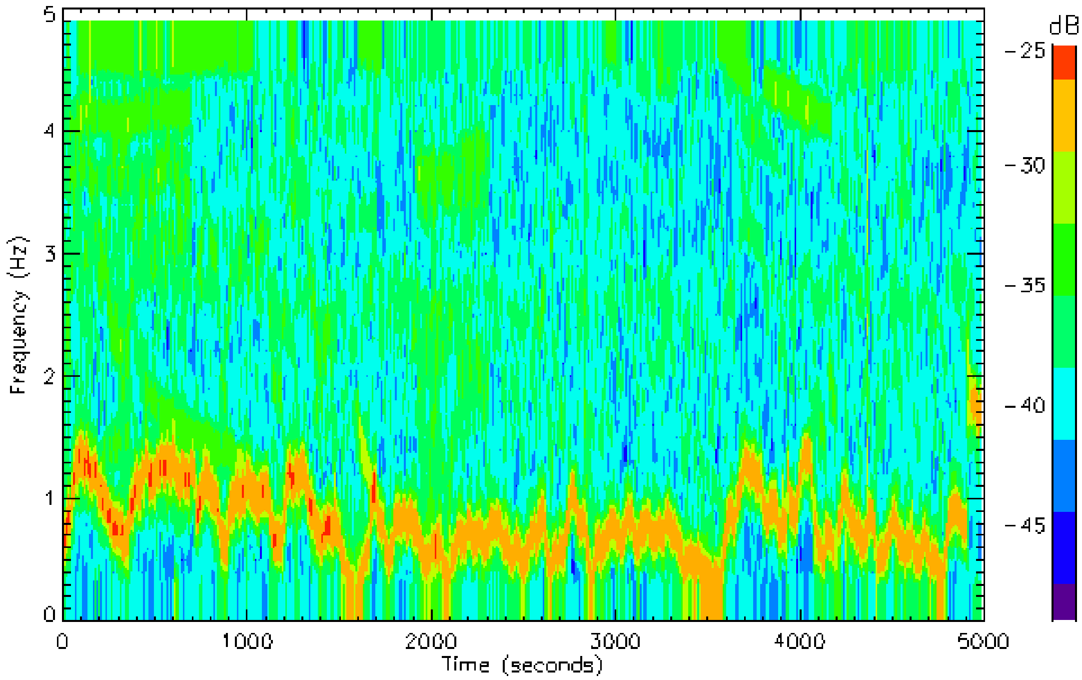


Figure 14. Spectrogram of the first 5000 seconds of Oct 25.

3.8 17-18 Nov 2015 (shore station G823 and G824)

The main aim of this analysis was to look for artifacts in the G824 spectra collected at high sampling rate (125 Hz) with the G824 magnetometer that could alias back into the MAD band if a low-sample rate (10 Hz) G823 magnetometer was used. This was done in response to recommendation (6a) from the Section 3.7. The informal letter reports are given in Appendices K, M, and N.

The conclusions were:

1) the segments with increased noise begin and end very quickly in the G824 data, just as they do in the G823 data sets, and have a fundamental of ~ 5 Hz, with harmonics near 10 and 15 Hz. However, the frequency slightly changes during the time that it is present. This can be seen in Figure 15.

2) the 10 Hz harmonic will definitely alias back into the MAD band if a G823 magnetometer is used. In addition, there appears to be a line at 9.9 Hz that will definitely alias back to 0.1 Hz if a G823 magnetometer is used.

3) the sources of the 5 Hz + harmonics, and the 9.9 Hz line are not known, but there will be LESS total noise aliased into the frequency band of interest if a G824 shorestation magnetometer was used instead of a G823. However, it was strongly recommended that

3a) a different basestation location be identified and data collected to determine the noise level, coherence with the undersea TF data, and compare the amount of noise reduction possible using both the Westlake basestation, and this new location.

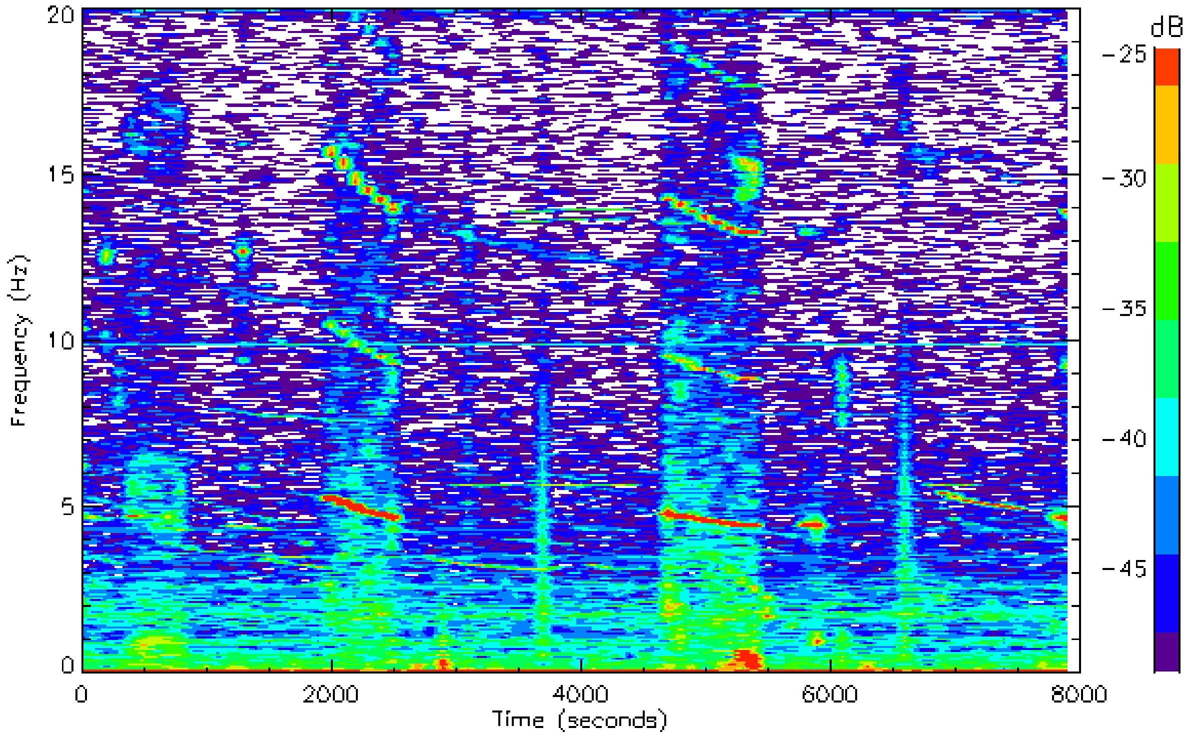


Figure 15. Spectrogram of G824 TF data collected on 17 August 2015.

3.9 14-17 Mar 2016 (shore station, undersea, and G824 at Everglades location)

The aims of these analyses were to determine if the noise due to the solar charging system was eliminated by moving the sensor from 40 to 100 ft from the charger. This was done in response to recommendation (1a) in Section 3.7.

The secondary aims were to verify there was still environmental noise at the Westlake Park basestation site that was not due to the charger, identify an alternative basestation location, and to compare the noise level, coherence, and noise reduction achievable at this alternative basestation site to the Westlake Park basestation. This was done is response to recommendation (3a) in Section 3.8. The informal letter reports are given in appendices O-R.

An alternative basestation site was identified at the eastern edge of the Everglades in a South Florida Water Management District protected area. Figure 16 shows the location of the Everglades site relative to the Westlake basestation and undersea magnetometer locations.

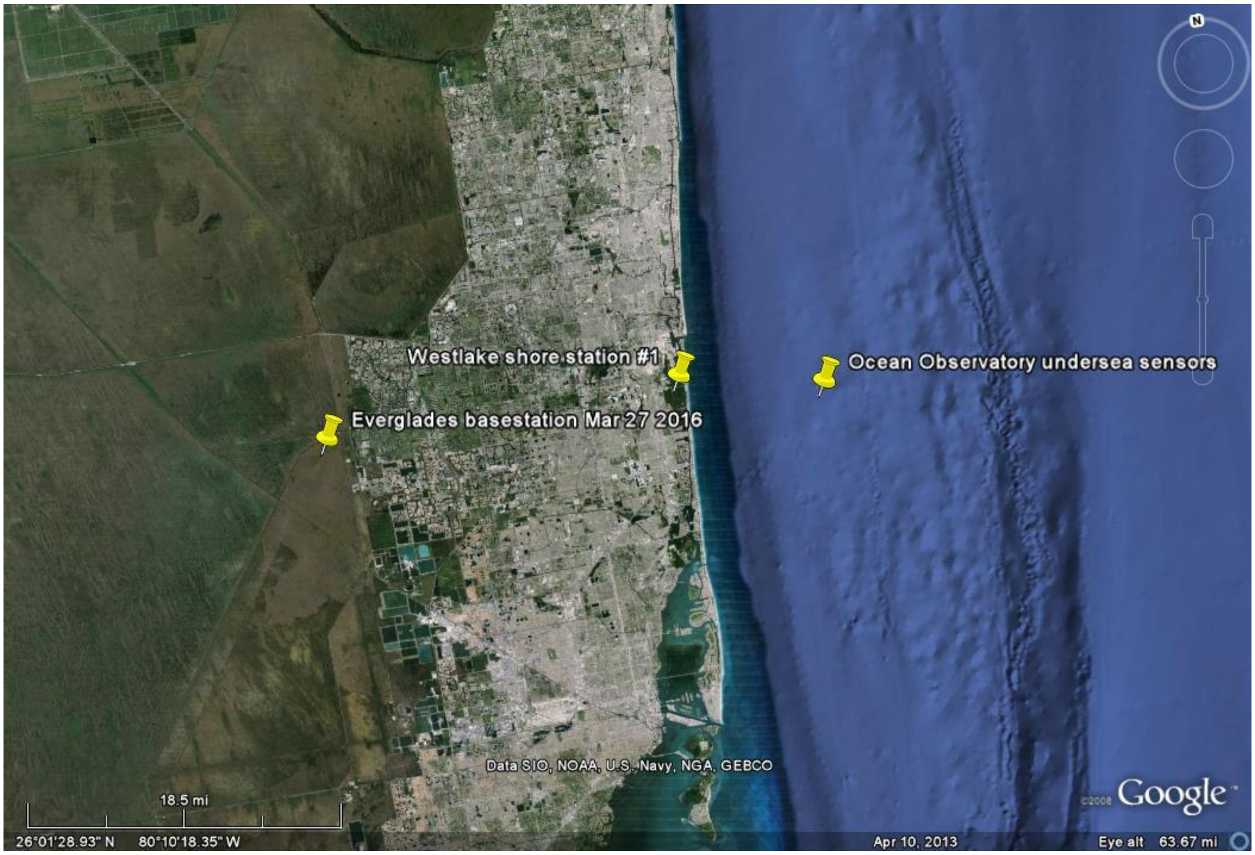


Figure 16. Location of Everglades basestation relative to the Westlake basestation and undersea sensors.

The conclusions from this analysis were:

1) The discrete lines at 0.5, 1, 1.5, etc. due to the charging station was clearly visible at 40 ft separation of the sensor and charging station, but were not visible at 100 ft separation.

2) However, there were clearly other environmental noise lines at 0.1 + harmonics visible + the noise at 4-5 Hz. Thus Westlake Park is not a good location for the basestation and a new site had to be found.

3) The white noise at the Everglades location was only 4 pT/rt Hz at 0.2 Hz and there were no obvious features other than the 60 Hz.

4) The Westlake data (blue) shows the discrete lines at 0.1, 0.2, 0.3, etc while the undersea (black) and Everglades signals do not.

5) The undersea and Everglades PSD shapes are very much alike while the undersea and Westlake PSD shapes differ significantly above 0.1 Hz.

6) There is better frequency-domain cancellation (FDC) noise reduction when using the Everglades magnetometer for noise reduction against the undersea magnetometer (red trace is slightly below the blue trace < 0.12 Hz in Figure 17).

7) There is higher coherence between the Everglades vs. undersea (Figure 18, red trace) than the Westlake vs. underwater (blue). This explains the improved noise reduction when using the Everglades sensor as the reference.

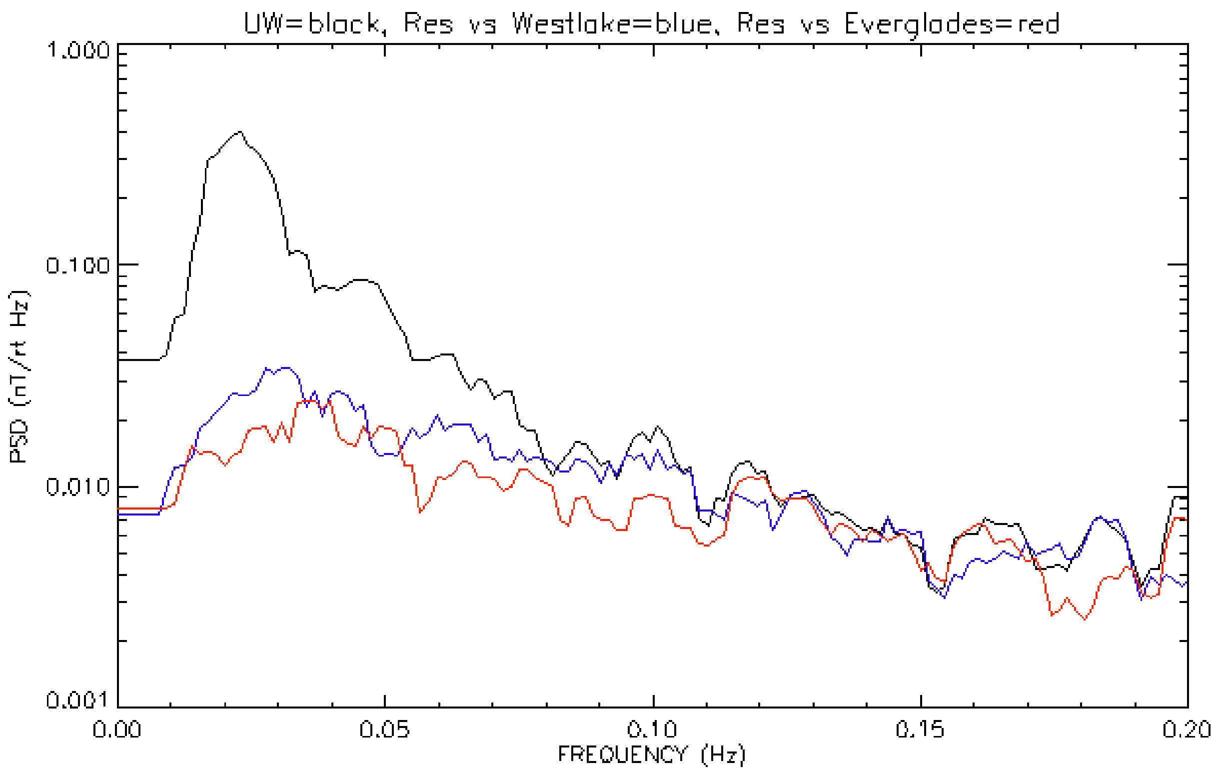


Figure 17. PSD of Undersea TF signal (black) vs. FDC Residual using Westlake (blue) and vs. FDC Residual using Everglades (red).

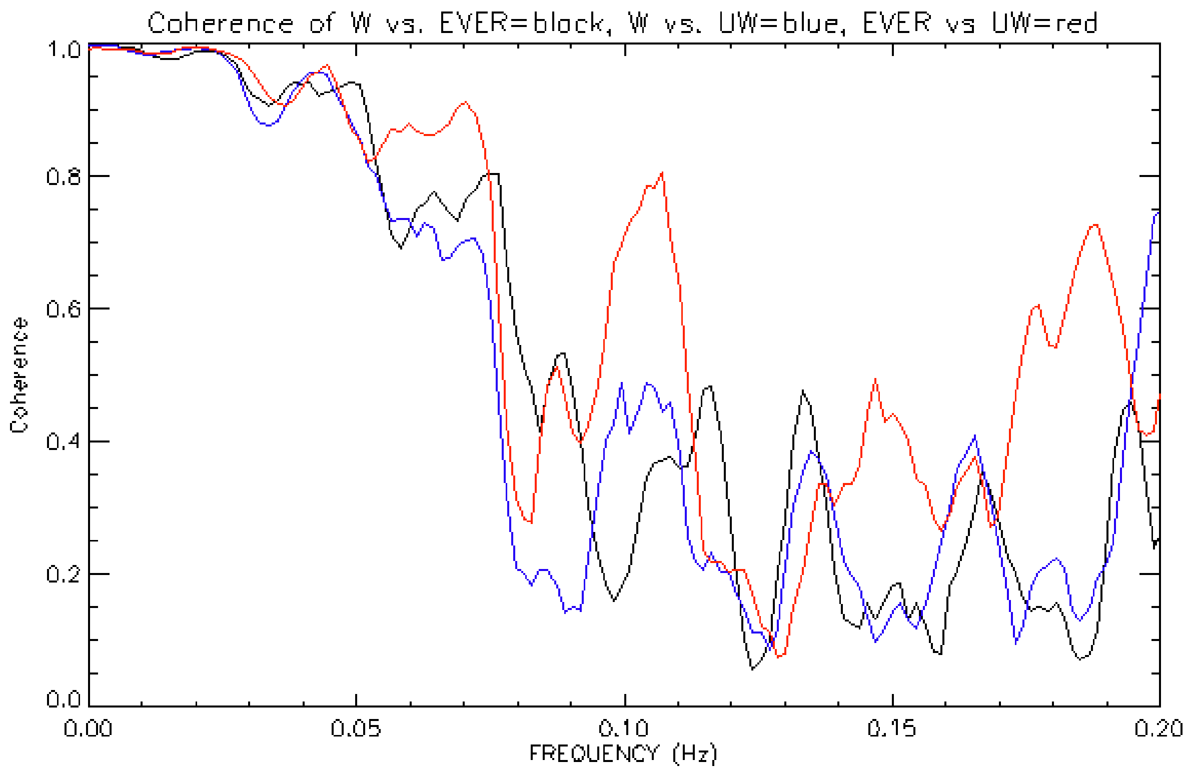


Figure 18. Coherence of Westlake vs. Everglades (black); Westlake vs. Undersea (blue); Everglades vs. Undersea (red).

4. Analysis of ADCP data

4.1 19-23 March 2015

A total of 5506 pings were recorded over the 5 days period. Data from this binary format were translated to an ASCII format using *WinADCP.exe* . WinADCP allows the user to preview the file and Export to the ASCII files. The data were viewed in IDL and the plots for the East, North, and Vertical velocity flow are shown below. Since the ADCP were set up to record 75 bins of usable data in a water depth of 264m, the last bin was 31.68m below the water surface. The plots were in-filled from near the ocean surface by extending shallowest value (bin75) up to surface. A median filter was used to remove outliers but this did not significantly change the structure of the visible features. Figures 19-21 show the East, North, and Vertical water velocities for the 1923 March 2015 data.

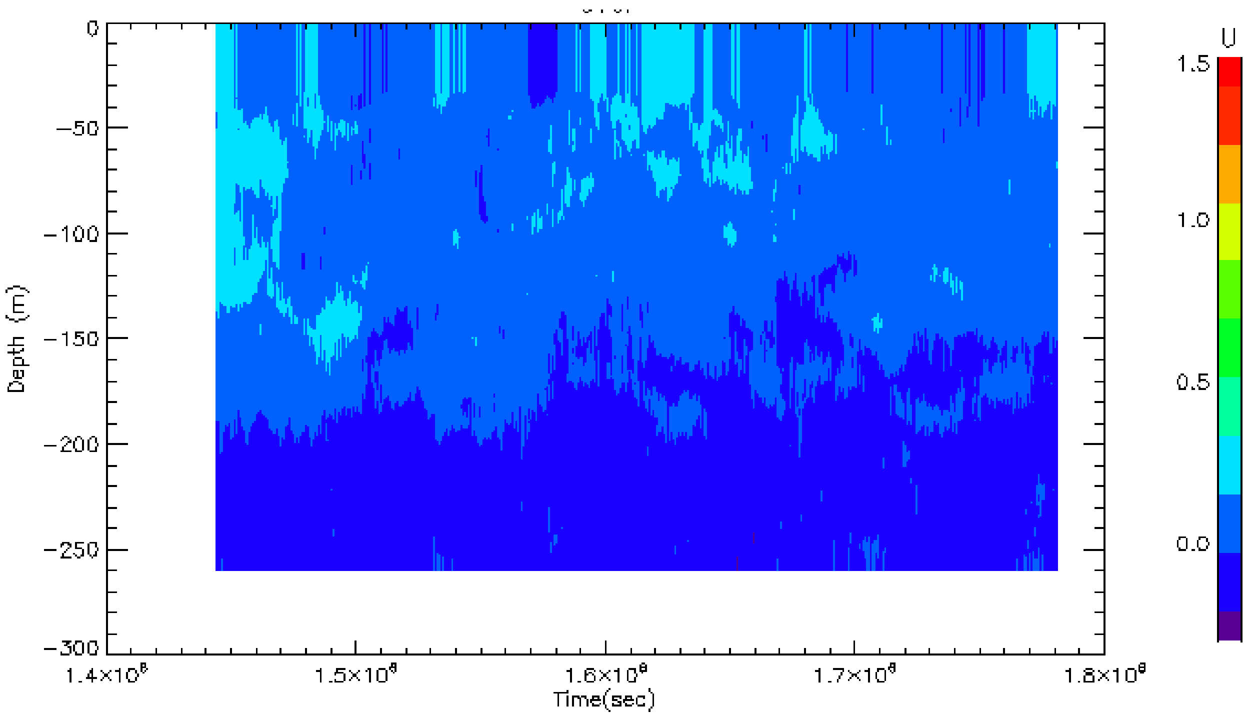


Figure 19. East velocity component.

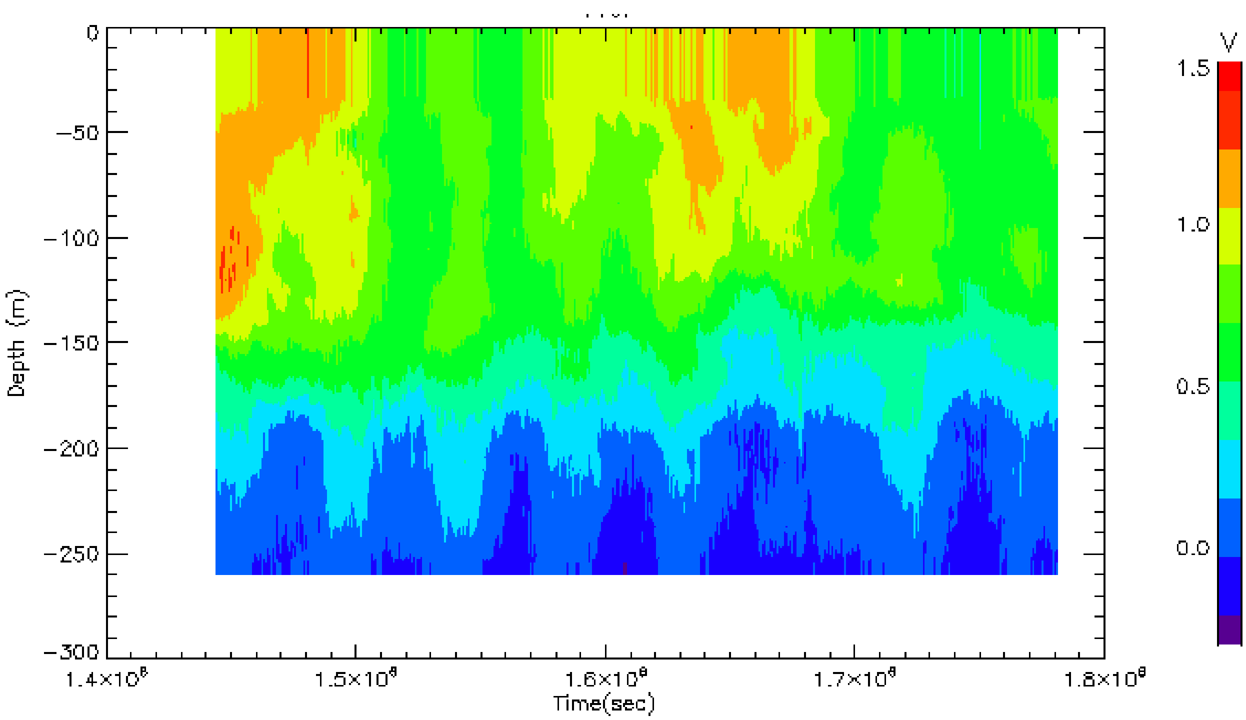


Figure 20. North velocity component.

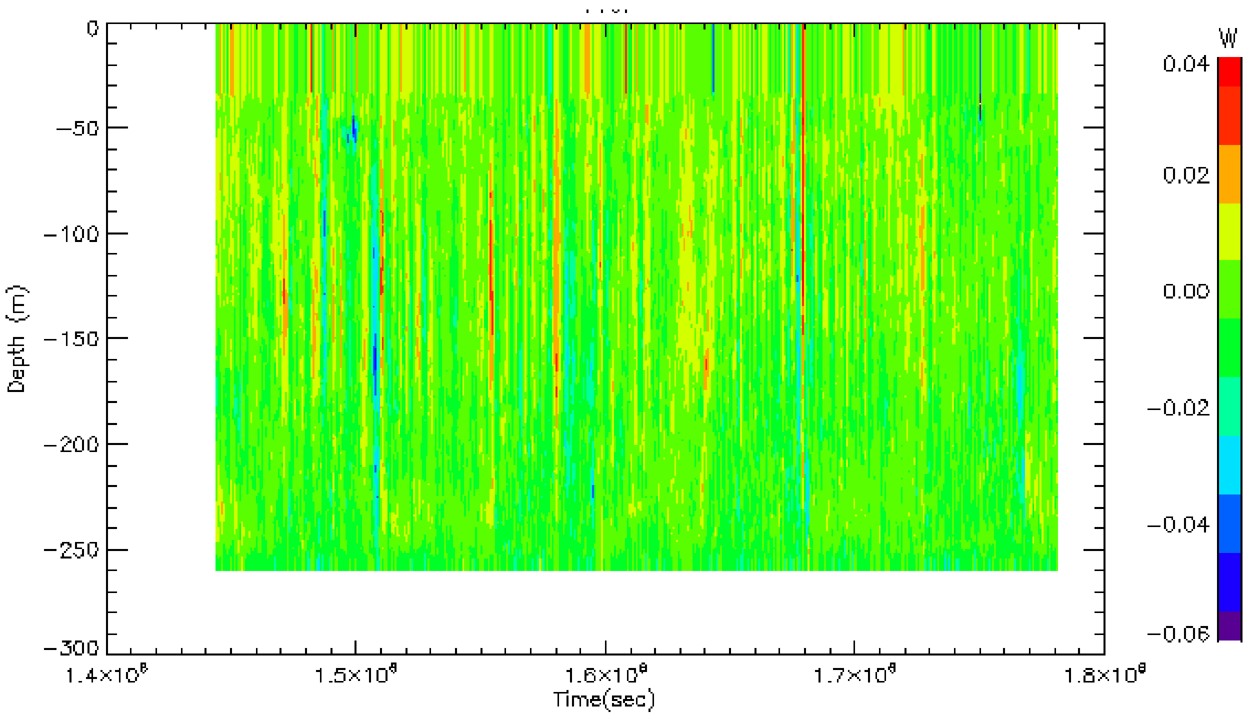


Figure 21. Vertical velocity component.

The main conclusions are:

1) the ADCP data do not have any spikes or artifacts that require correction prior to further analysis, although a median filter did slightly improve the visibility of the oceanographic features. Thus the quality of the ADCP data is adequate for the Ocean Observatory program.

2) the ocean structure shows a significantly deeper thermocline and higher velocity structure during this portion of the year.

4.2 4-7 Sept 2015

A total of 6772 pings were recorded over the 6 days period. Data from this binary format were translated to an ASCII format using *WinADCP .exe* . The data were viewed in IDL and the plots for the East, North, and Vertical velocity flow are shown below. Since the ADCP were set up to record 74 bins of usable data in a water depth of 264m, the last bin was 34.68m below the water surface. The plots were in-filled from near the ocean surface by extending shallowest value (bin74) up to surface.

Complimentary magnetometer files were recorded during this same period to evaluate the data acquisition system. A significant amount of the magnetometer analysis was done for Sept 7 and some unusual features were observed. The plots below focus on the Sept 7 ADCP data to look for any obvious effect that the oceanography could have on the magnetic sensor equipment. Figures 22-24 show the East, North, and Vertical water velocities in the Sept 7 2015 data.

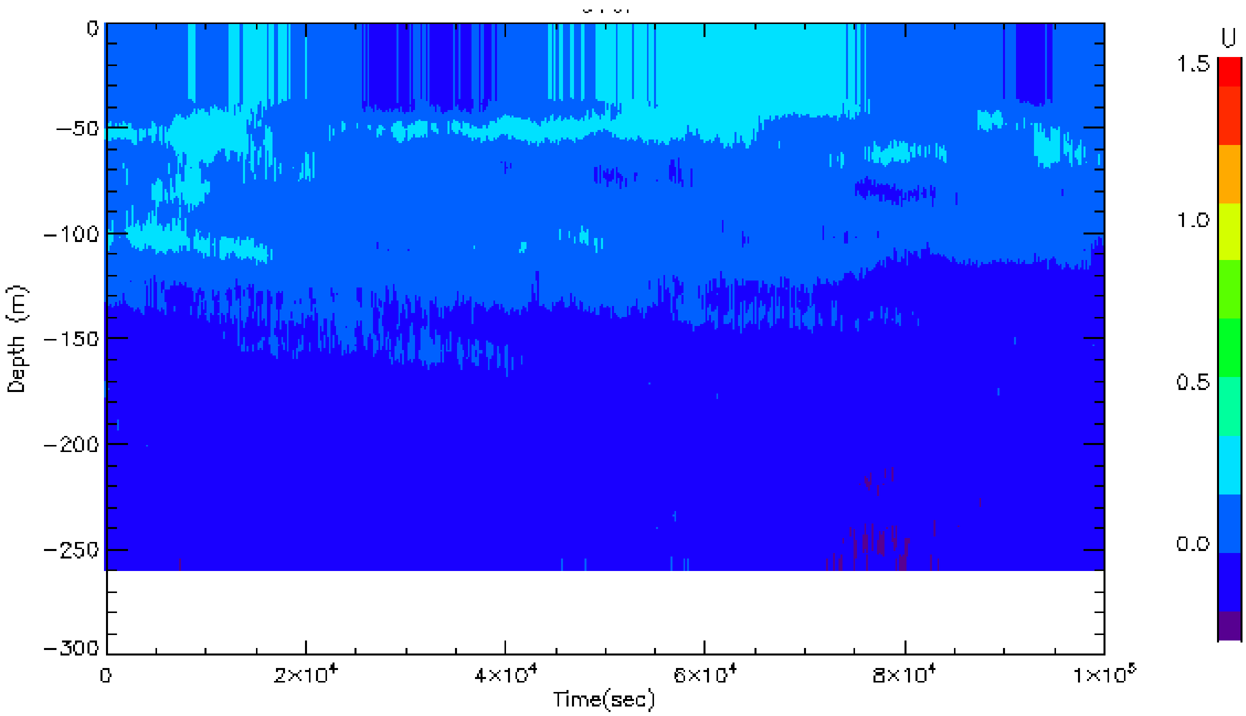


Figure 22. East water velocity from the ADCP site zoomed to the day Sept 7.

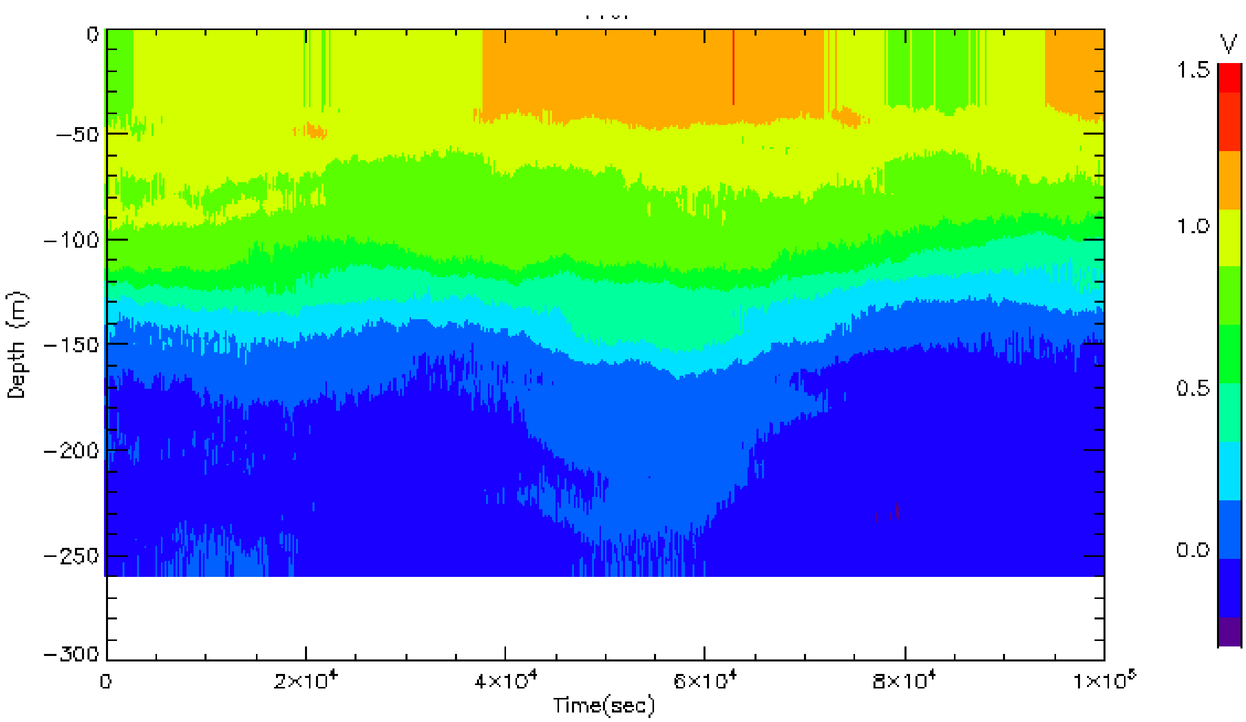


Figure 23. North water velocity from the ADCP site zoomed to the day Sept 7

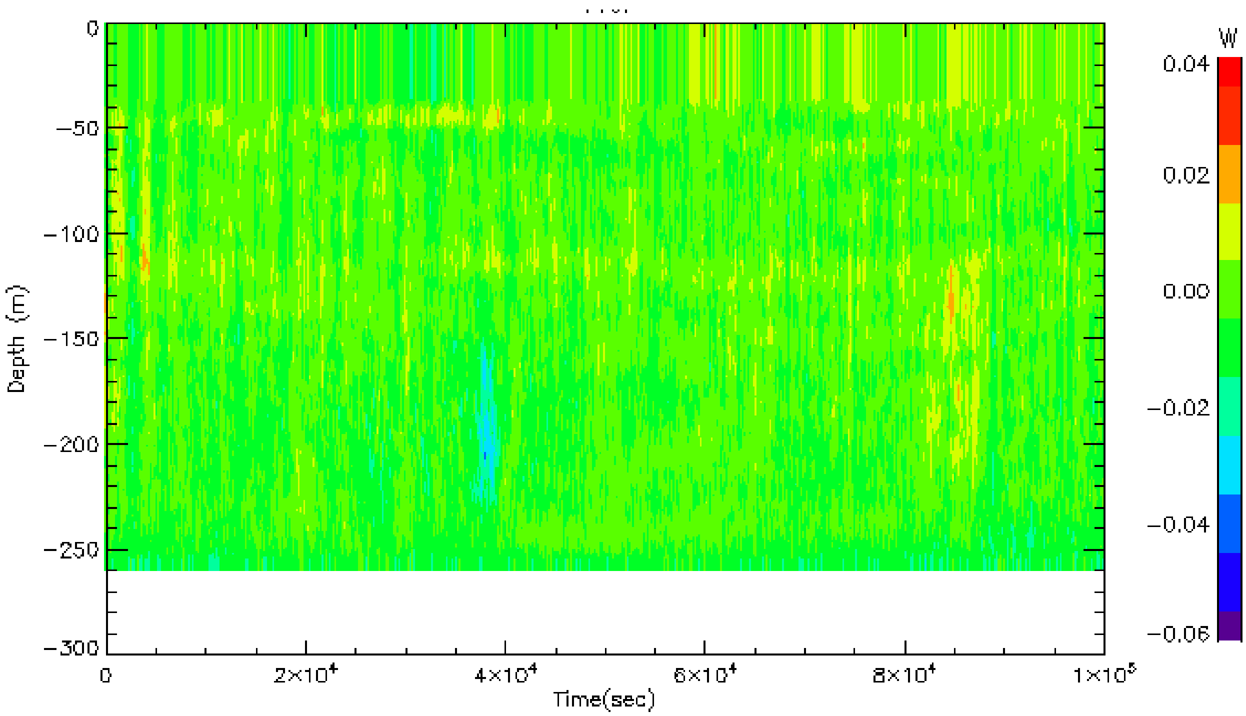


Figure 24. Vertical water velocity from the ADCP site zoomed to the day Sept 7.

Examination of the September 7 ADCP velocities indicates that the velocities near the bottom are not sufficient to move the magnetometer platform and sensor. The north velocity does show a significant deviation during the day around Time second 50000, but this is a long term excursion of the velocities not a short term feature. As a result, there are no significant short-term features that could create any anomalous excursions on the undersea magnetic sensor.

5. Conclusions, recommendations, and status of work topics

The issues, recommendations, solutions, and status of each work topic are summarized in Table 3.

Table 3. Issues, recommendations, solutions, and status of each work topic.

Topic	Issue	Recommendation/Solution	Status
Undersea time stamps	Not enough resolution	Change data acquisition software	Tried PUTTYLOG.exe
	Poor data format	Change data acquisition software	Labview D/A solves
	Bad time stamp	NSWC make automatic connection to UTC time server more robust	Solved
Shorestation hardware	G823 failed	Send to manufacturer for repairs	Solved
Shorestation noise	Charging station-generated noise	Determine sensor-charger separation required to eliminate noise	100 ft cable solved problem
	Environmental noise (transients & AC)	Check to see if problem is aliasing, or if it could be solved by using a G824 magnetometer	Need a new shorestation site
Undersea magnetometer noise	Cause of "Quiet" period at night?	Check for noise created by ADCP or electric currents flowing to undersea sensors	Not related to ADCP or electric currents. Undersea sensor functioning properly
Alternate shorestation	Find a shorestation site that has less noise than Westlake Park	Everglades location 20 miles west of Westlake Park	Very low noise level and no spectral features other than 60 Hz
Coherent and geomagnetic noise reduction	Is the coherence between the Everglades and undersea magnetometer adequate for geomagnetic noise cancellation?	Everglades shorestation gave better coherence and better geomagnetic noise reduction than did the Westlake Park shorestation	NSWC will use the Everglades site for the shorestation
Swap G823s for G824s (10 x lower noise and higher sampling)	Different footprint, power, and bandwidth needed	Re-design mounts to accommodate the different G824 sensor footprint, and verify the power and bandwidth requirements are met by existing cabling. Change the Labview data acquisition software to filter and sub-sample the undersea magnetometer data if required	NSWC has already begun to address these recommendations
ADCP data quality	Time-stamp? Missing Data? Bad data?	The top bin is 31.68 m below the surface so there is no wave motion being measured by the ADCPs	Use sensors and data acquisition software as it is

References

1. Podney, W., 1975: Electromagnetic fields generated by ocean waves, J. Geophys. Res., 80, 2977-2990.

2. Magnetometer shore reference station assembly and operation, NSWC Carderock – Ft. Lauderdale Division working document

3. http://www.geometrics.com/geometrics-products/geometrics-magnetometers/magnetometer-datasheets/

Appendix A: Analysis of Nov 15 underwater and basestation G823 data

IDL code: ftlauderdale_Feb_2015.pro

Input files: Base = TOA5_56936_MagData_45_2014_11_15_0000.flagged
UW = 20141115_MAG_LOG

Time stamp on Base = HH, MM, SS.ss based on data acquisition clock
Time stamp on UW = MATLAB time in decimal days where 735918.000000+1 second = 00:00:01.00 of Nov 15

Sample rate = 10 Hz in both cases

1. Basestation data

The time stamp on the basestation appears to be in UTC because on a previous comparison of Jan 5 data from the basestation and the USGS station at San Juan showed excellent coherence without any major time delays. Thus we believe the timestamp on the SFOMF basestation is UTC.

The original basestation TF data contains many single-point "NaN" values which I do not believe are part of the ASCII stream that comes from the G823 sensor. Thus I believe it is being introduced by the Campbell data logger. They occur at roughly constant intervals (45 minutes), but the pattern is not exactly the same. Since they are single-point in nature, it is easy to simply replace the "NaN" values with a flag (in this case 50000.000) and in the IDL routine, I simply replace any data points with the field value 50,000.000 with the field value from the previous data point.

However, the actual basestation field measurements are quite noisy. In fact they are considerably noisier than the undersea TF data. The Figure 1 shows an assortment of noise mechanisms on the basestation TF data from Nov 15. There are quite a few single point glitches as well as periods where the overall noise level increases dramatically (e.g. dp>15000 in the Figure 1). More detailed analysis of the high-noise region (dp > 15000 in Figure 1) shows that it is a high amplitude discrete line that is changing in frequency over a short period of time. This is shown in Figure 2.

Previous data sets did show the single-point glitches, but the areas of overall noise increase were not seen before. This could be indicative of a failing G823 sensor, or it could be poorly oriented in the Earth's field.

There were two large anomalies of several hundred nT that had to be removed by fitting a linear trend across the roughly 40 seconds where they were present. These anomalies were quite smooth so they were clearly a real change in magnetic field – the most likely explanation is that a vehicle drove up to the basestation location, then turned around and drove away.

Finally, there were some smaller anomalies of ~ 1 nT in height that again were smooth in nature – some were dipole-like and some were more like rounded square waves. These anomalies were not seen in the underwater TF data so they were not geomagnetic in origin. They persisted for only 10-20 seconds so they might have been associated with a boat going by on the waterway, or conceivably a very large, slow-moving vehicle on the highway. However, previous data sets did not show such anomalies and it is unlikely that the highway traffic would have changed that much on Nov 15.

In summary, the major issues with the basestation data were:

1) NaN values in the raw data
2) higher noise than the underwater sensors, which suggests that simply subtracting the basestation TF could actually ADD noise
3) man-made anomalies that have to be removed manually before any further analysis can be done.

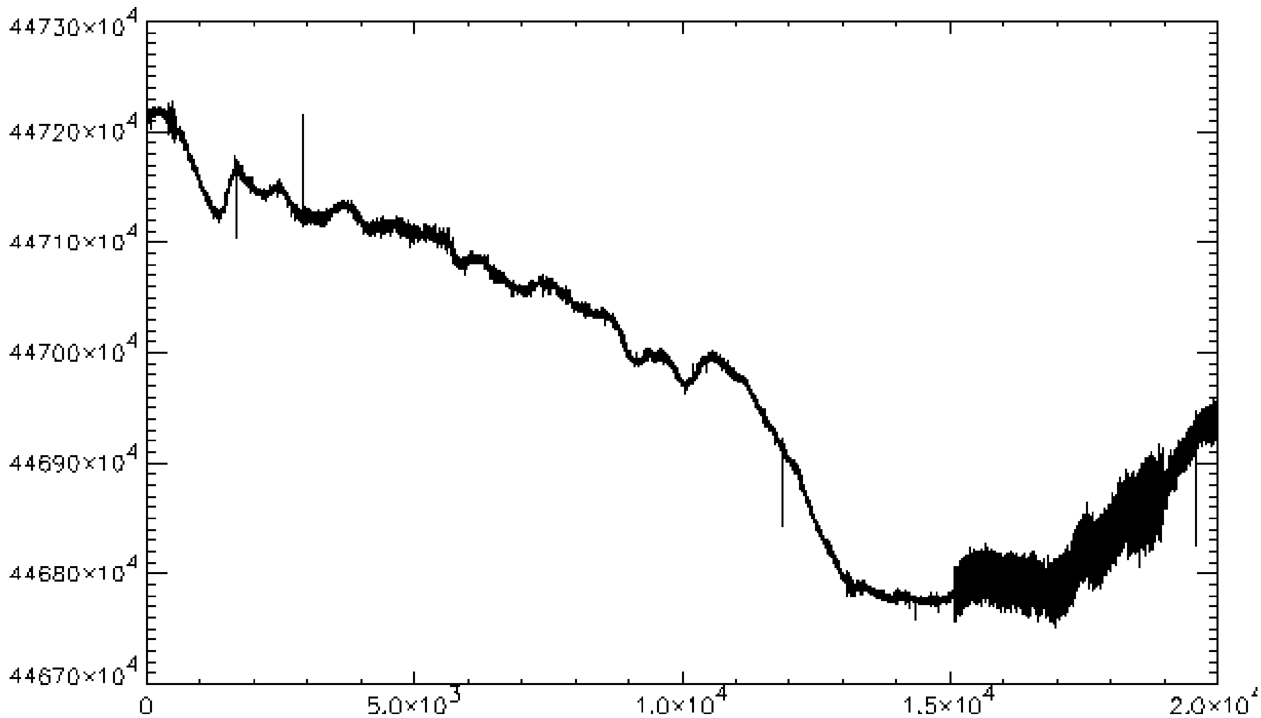


Figure 1. Base TF signal for 20000 dp (= 2000 seconds) on Nov 15, 2014.

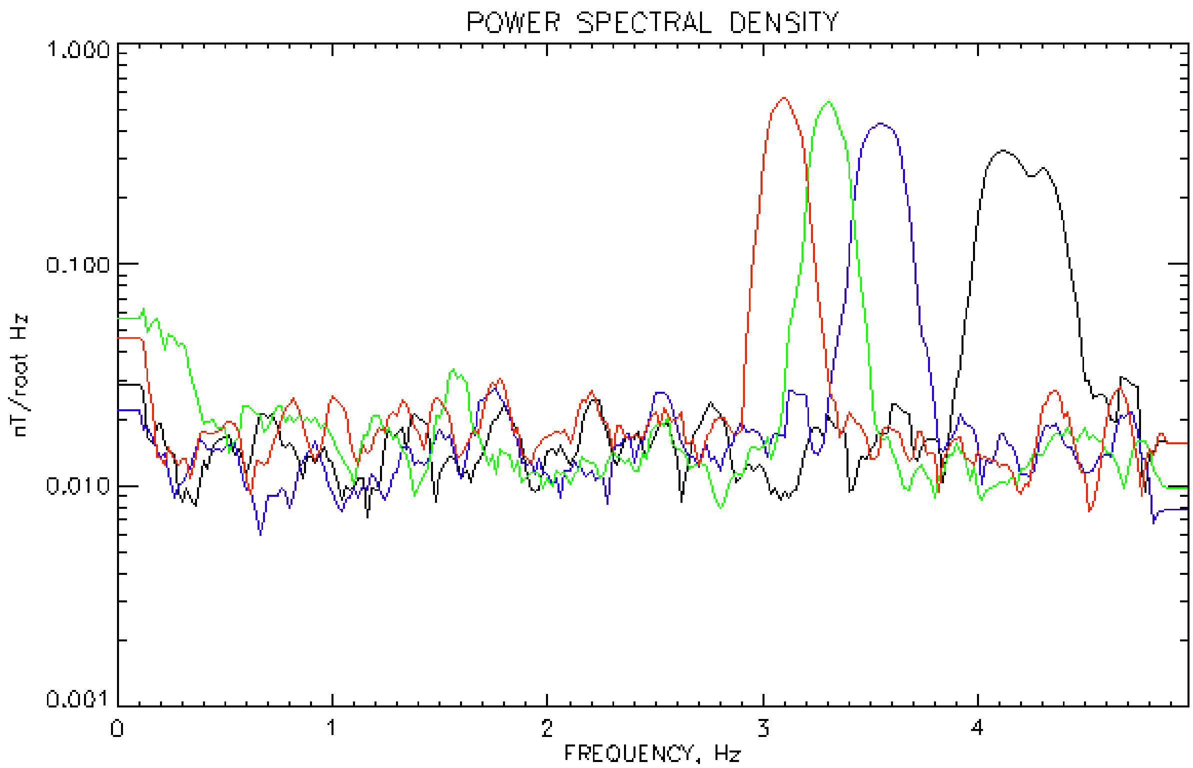


Figure 2. PSDs of consecutive 50 second (500 dps) blocks data from the noisy region identified in Figure 1.

2. Underwater data

The timestamp on the underwater data is applied using REALTERM.EXE which logs data from the serial port. The stamp chosen was “MATLAB TIME” which is decimal days since Jan 0, year 0000. The resolution of this time stamp is 0.000001 days = 0.0864 seconds. Unfortunately 10 Hz data implies a change in time from one sample to another of 0.1 seconds. Thus the MATLAB TIME stamp is just on the borderline of being able to discern the change in time and it is certainly not good enough if one wishes to do any interpolation or re-sampling based on the timestamp. For this analysis I have assumed that the G823 sampling rate is EXACTLY 10 Hz, and that the timestamp for the first data point is EXACTLY correct. All subsequent data points are sampled EXACTLY 0.1 seconds after the previous sample. While this is adequate for relatively short data files (say 1 day), it is quite possible that the G823 oscillators will drift over the course of several days, making time alignment with the basestation difficult. The timestamp applied to the underwater data must be improved.

Also, the REALTERM timestamp is derived from the recording computer. In this case, the recording computer was not set to UTC. In fact it was set to approximately local time (UTC+5 hours) +62 seconds. This was determined by comparing the measured basestation and underwater TF data from Nov 15 and adjusting the lag until the geomagnetic variations coincided. However, as mentioned before, the basestation data were much noisier so an exact match using correlation techniques was not applied.

The Underwater TF data clearly contained two ship signatures. These portions were not used in any analysis. Figure 3 shows the basestation and underwater TF data plotted vs. time, where the underwater time was corrected by 5 hours, 62 seconds, and no ship signatures were present.

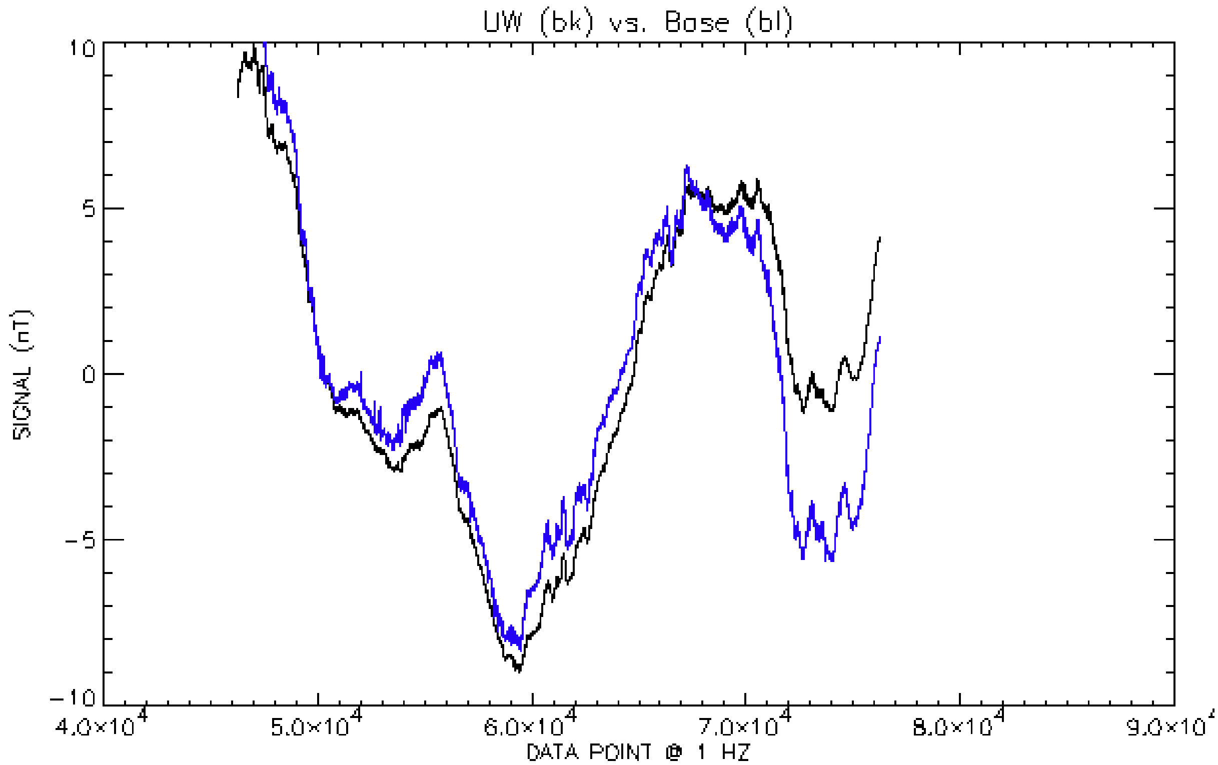


Figure 3. Underwater TF (black) vs. Basestation TF (blue) in a region with no anomalies in the Basestation data.

3. Analysis

Figure 4 shows the power spectral densities (PSDs) of the time-aligned Basestation and Underwater TF signals shown in Figure 3. The data were filtered with a 5^{th}-order low-pass filter with a 3 dB point at 2 Hz prior to calculating the PSDs. It is interesting to note that the amplitude of the geomagnetic activity centred on 0.05 Hz is NOT the same amplitude. It is perfectly conceivable that the amplitudes would not be the same as the "coastline effect" predicts that the amplitudes should be different if the conductivity of the land is significantly different from the conductivity of the seawater. This was not seen in previous data sets where the geomagnetic activity at the basestation was the same amplitude as measured underwater. However, the water depth is much greater for this installation so there could also be a skin depth effect that is reducing the amplitude of the geomagnetic signals. Figure 5 shows the PSD of the basestation TF, corrected by a skin depth computed assuming a seawater conductivity of 5 Siemens and the actual depth of the Underwater sensor (850' ~ 259 m). While the spectra do match everywhere (because of the spikes see in the Basestation TF), the skin-depth corrected values for the geomagnetic signals centred at 0.05 Hz do agree with the measured Underwater geomagnetic signals.

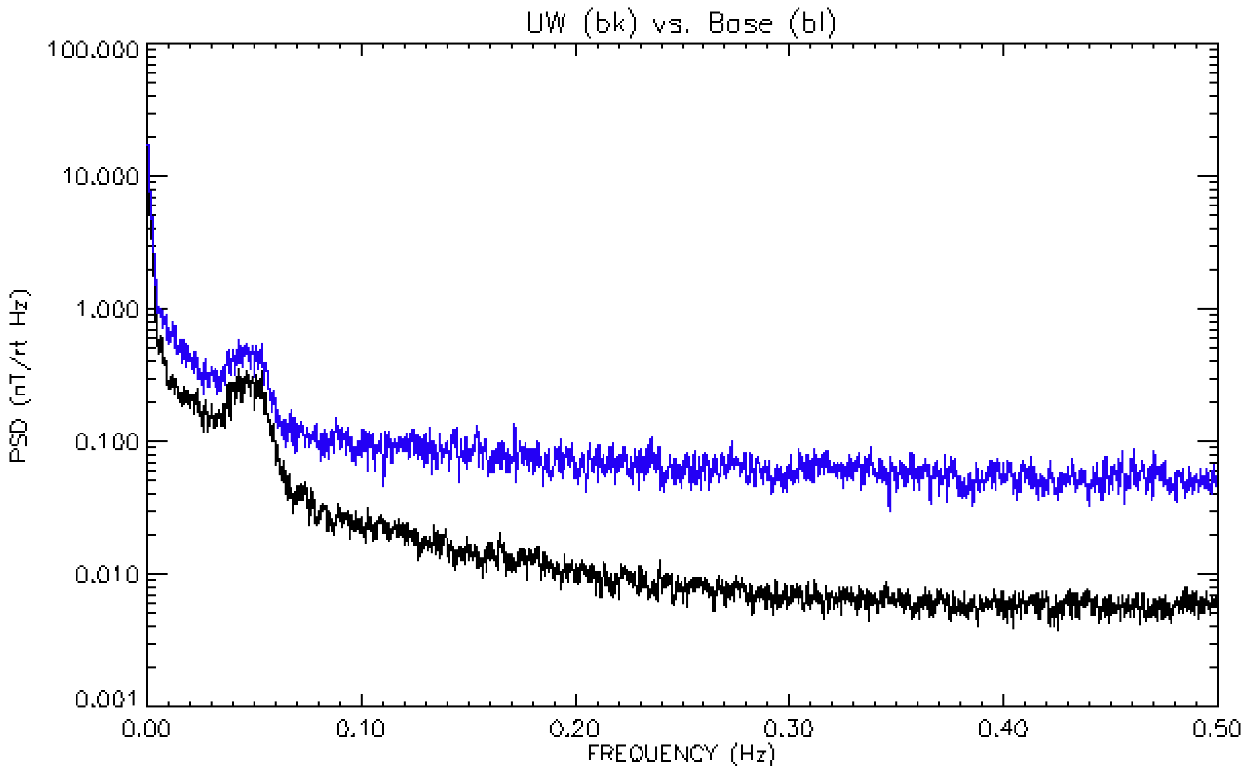


Figure 4. Power spectral densities of Underwater and Basestation TF data shown in Figure 3.

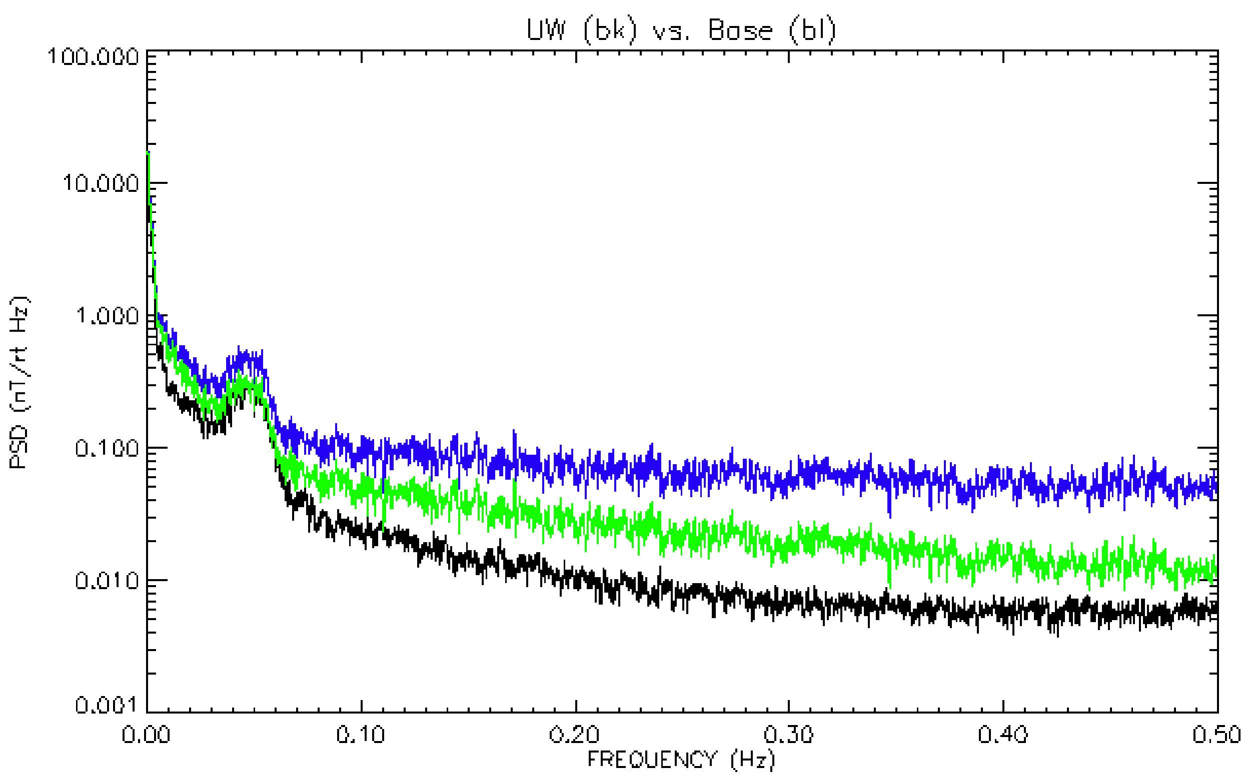


Figure 5. PSD of Underwater TF (bk), Basestation TF (bl) and Basestation TF corrected for skin depth attenuation to depth of the Underwater Sensor (gr).

The same data as shown in Figures 3-5 were analysed to determine how much of the geomagnetic signals can be removed from the underwater TF data. If a simple subtraction is being used, then the Basestation TF data should be corrected for the skin depth attenuation. However, it is much simpler to use a frequency-domain cancellation (FDC) technique which calculates a phase and amplitude relation between the Underwater and Basestation TF at each frequency bin as that automatically accounts for both the skin-depth attenuation and possible shoreline effect. To apply this algorithm the signals must be zero-mean so both TF signals were filtered with a 4th-order 0.002 Hz high-pass filter.

Figure 6 shows a plot of the filtered Basestation TF, Underwater TF, and FDC Residual and Figure 7 shows the PSDs of the same data. Notice that the geomagnetic signals have been almost completely removed, but there still appears to be a small artifact centred on 0.05 Hz There may be hints of oceanic signals as individual anomalies between 47000 and 53000 seconds, but they are quite small in amplitude.

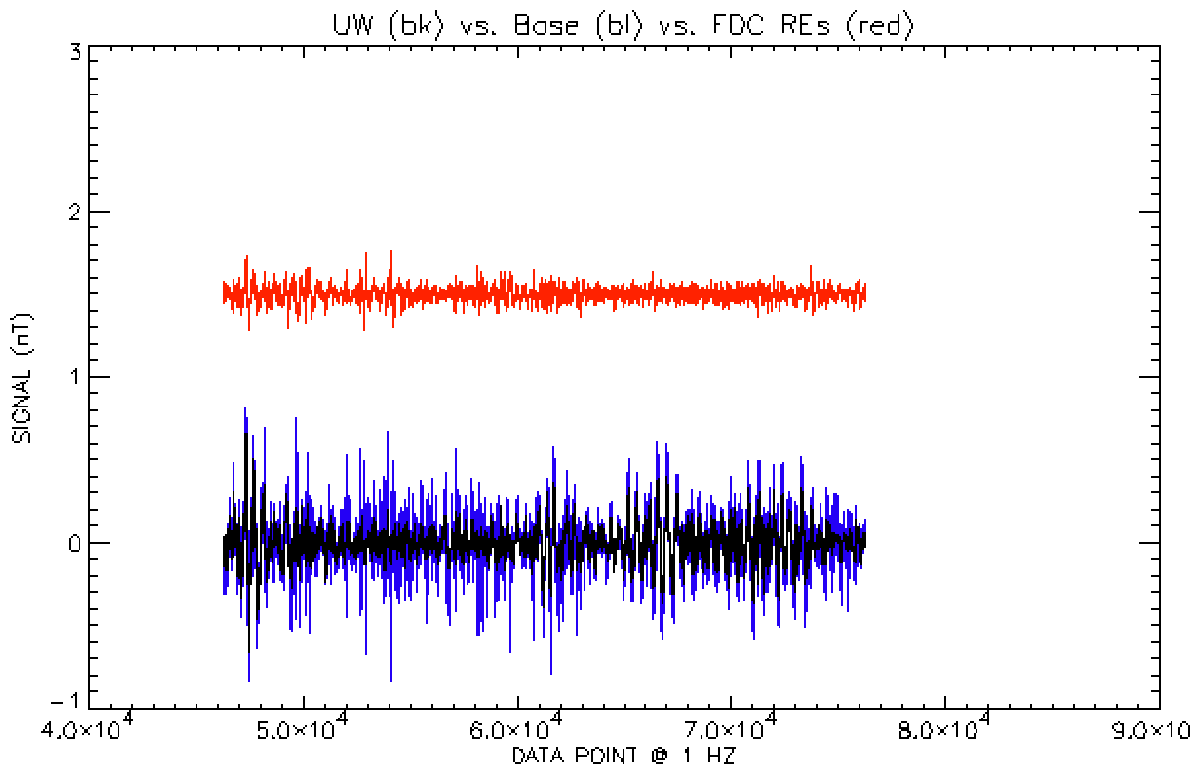


Figure 6. 0.002 Hz, 4th-order HP filtered Underwater TF (bk), Basestation TF (bl), and FDC Residual (red) for data segment shown in Figure 2.

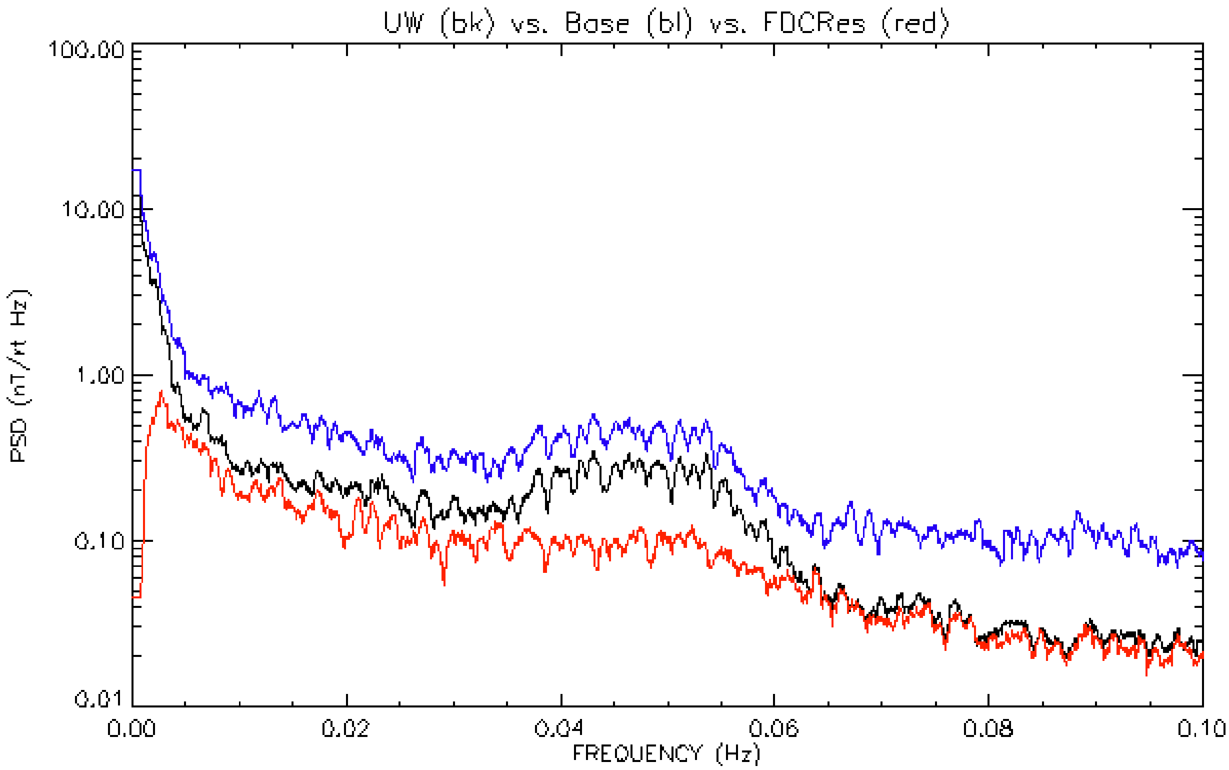


Figure 7. PSD of data shown in Figure 5, in the 0 - 0.1 Hz band.

4. Conclusions

The main conclusions are:

1) The timestamp on the basestation data is UTC

2) the basestation magnetometer appears to have spikes and excess noise compared to previous trials. It should be verified that the sensor is aligned properly and that it is not failing. This can be done by using two G823 magnetometers at the basestation locale and comparing the data. If the excess noise is seen on both sensors, then it is man-made noise, not a failing sensor that is the problem. In this case, another basestation location should be found. If this is not the case, then the failing sensor should be replaced.

3) There are also man-made anomalies in the basestation data that have to be removed manually before the data can be used for geomagnetic noise reduction.

4) The timestamp on the Underwater TF data is inadequate. Because it uses the recording computer's time when the serial data arrives, this computer should be set to UTC and periodically updated (once an hour if possible) to match the basestation time.

5) The timestamps available through REALTERM are not accurate enough for 10 Hz timetags. Don Pugsley has suggested using the open-source program "Putty" to obtain millisecond timetags. This should be investigated.

6) The Underwater TF data have no excess spikes, but they clearly show an attenuation of the geomagnetic signals due to the skin-depth of seawater. If the Basestation TF data are to be used for geomagnetic noise reduction, then either the attenuation must be calculated and accounted for, or a frequency-domain method of noise cancellation can be used.

7) The Underwater data contain ship signatures and one must be careful not to include those signatures when calculating the transfer functions for the FDC method.

8) There was no obvious problem with coiling the G823 cable or running the electronics close to the sensing head in the underwater installation. Similar sensor housing and cabling methods should also work with the G824 magnetometers.

Appendix B: Feb 11 underwater magnetic data

Use Word to read in the file 20150211-Pugsley-MagLog.txt Remove the header and everything until past the last “Putty log” banner.

Save as 20150211-Pugsley-MagLog.cor with Windows encoding creates a file structure like this:

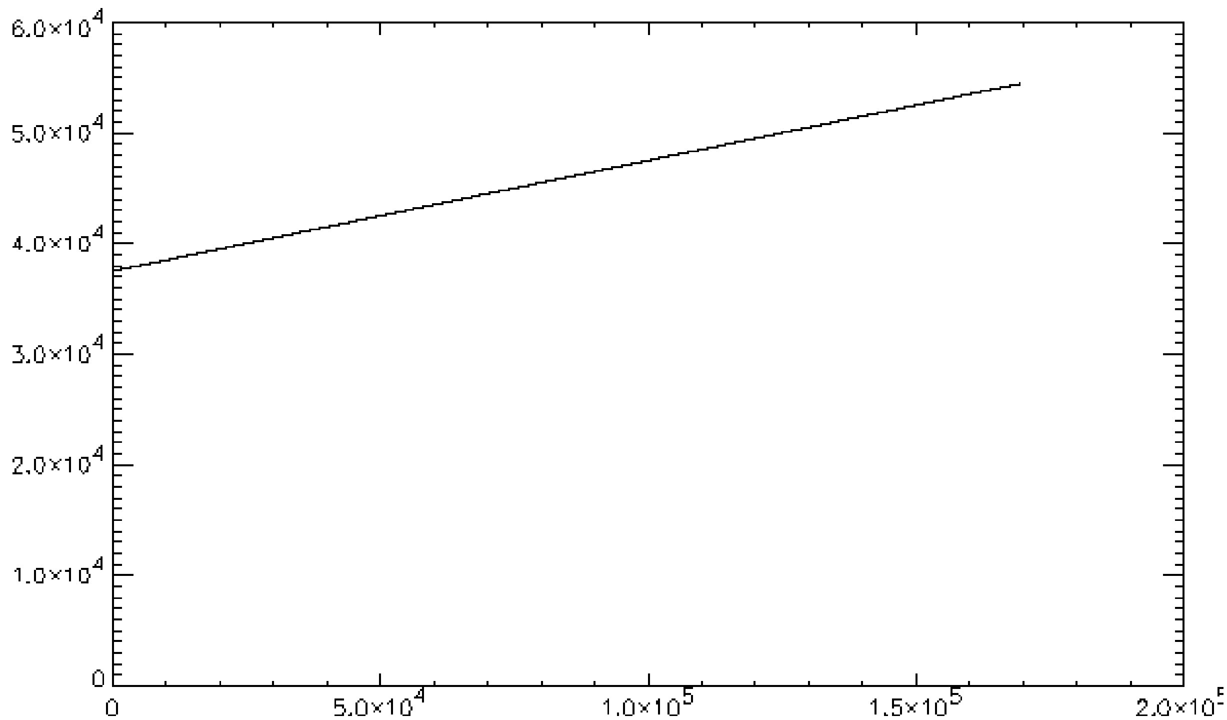
```
 15 02 11 10 25 21 137 $ 44339.092,1804
 15 02 11 10 25 21 137
 15 02 11 10 25 21 137 $ 44339.072,1770
 15 02 11 10 25 21 137
```

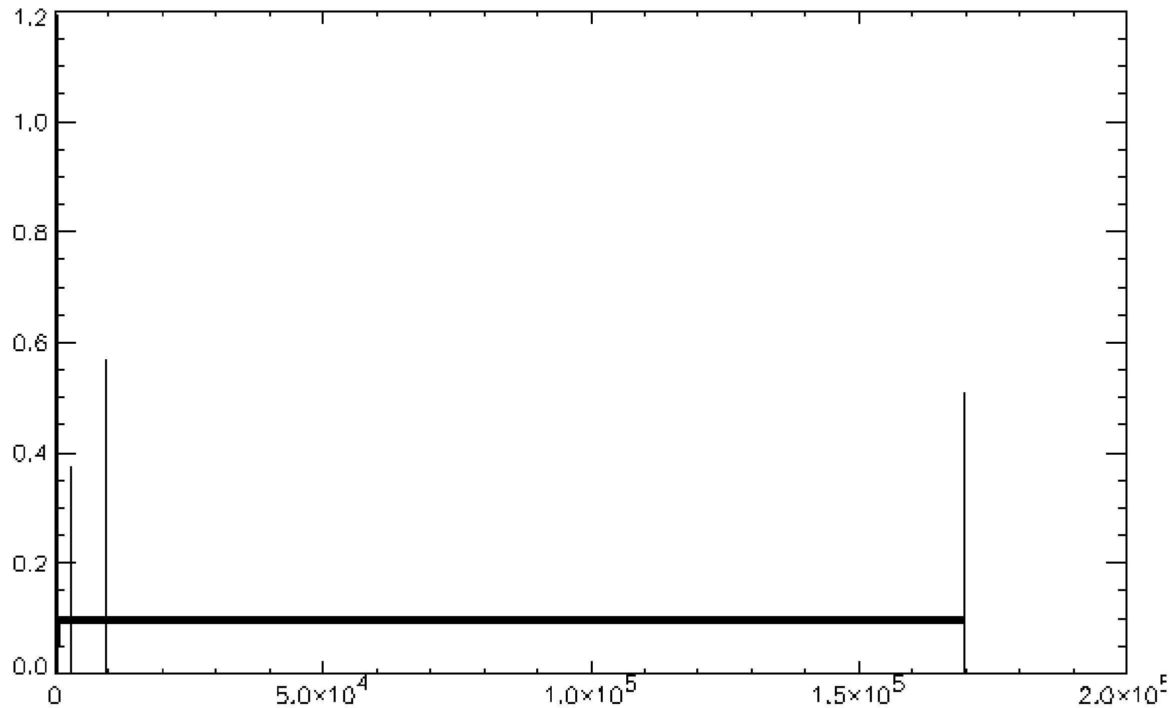
Use dfordPutty_FtLauderdale.pro to read into IDL

uwtime=uw(3,*)*3600.d0+uw(4,*)*60.d0+uw(5,*)+uw(6,*)/1000.

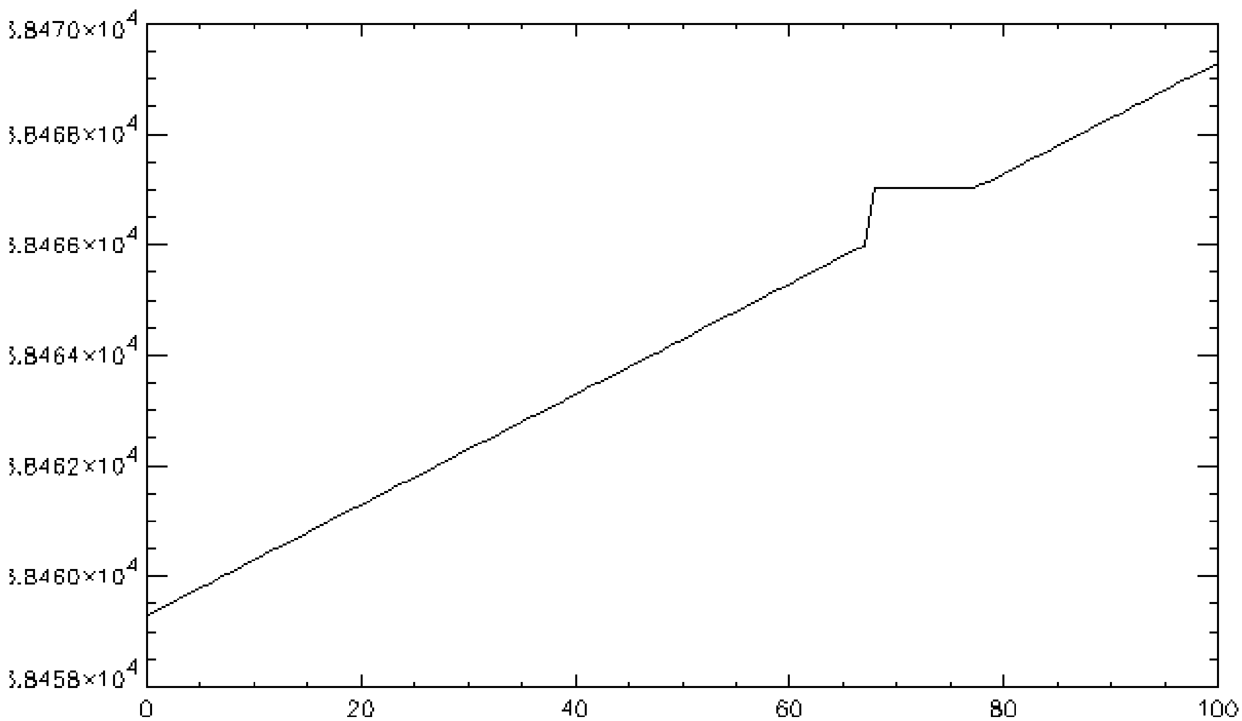
7^{th} column of uw = uwtf

Here is a plot of the uwtime and derive of uwtime:

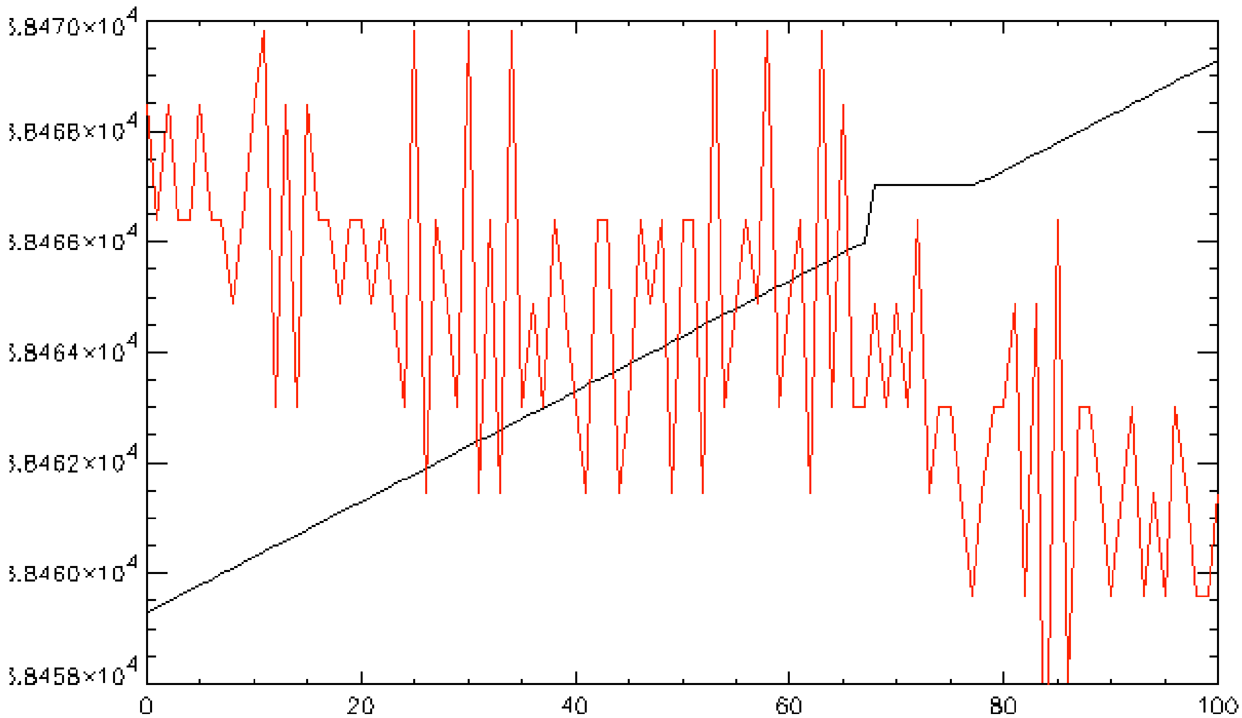




There are clearly still some problems associated with the time. Here is what the uwtime glitch looks like near DP 9470



Here is a relative plot of the uwtime and uwtf of the same feature. Clearly only the time is affected – the TF data is not.

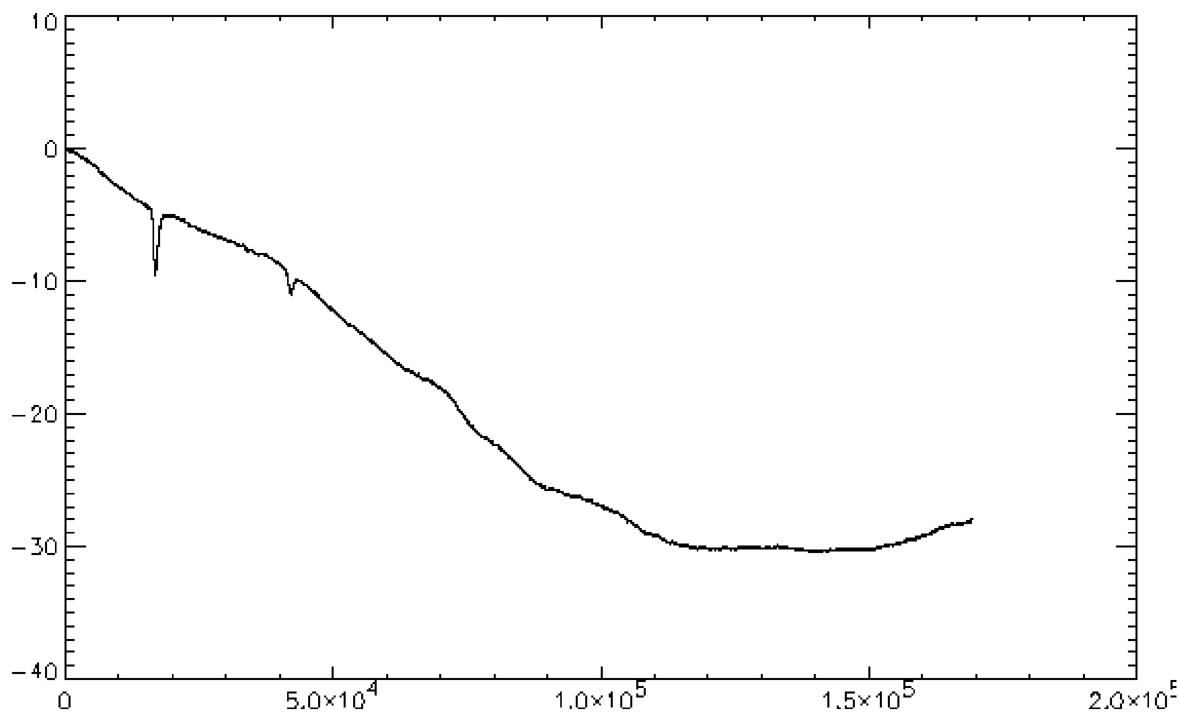


Here are the actual times for DP 9460:9480 and the predicted times assuming DP 9460 is valid

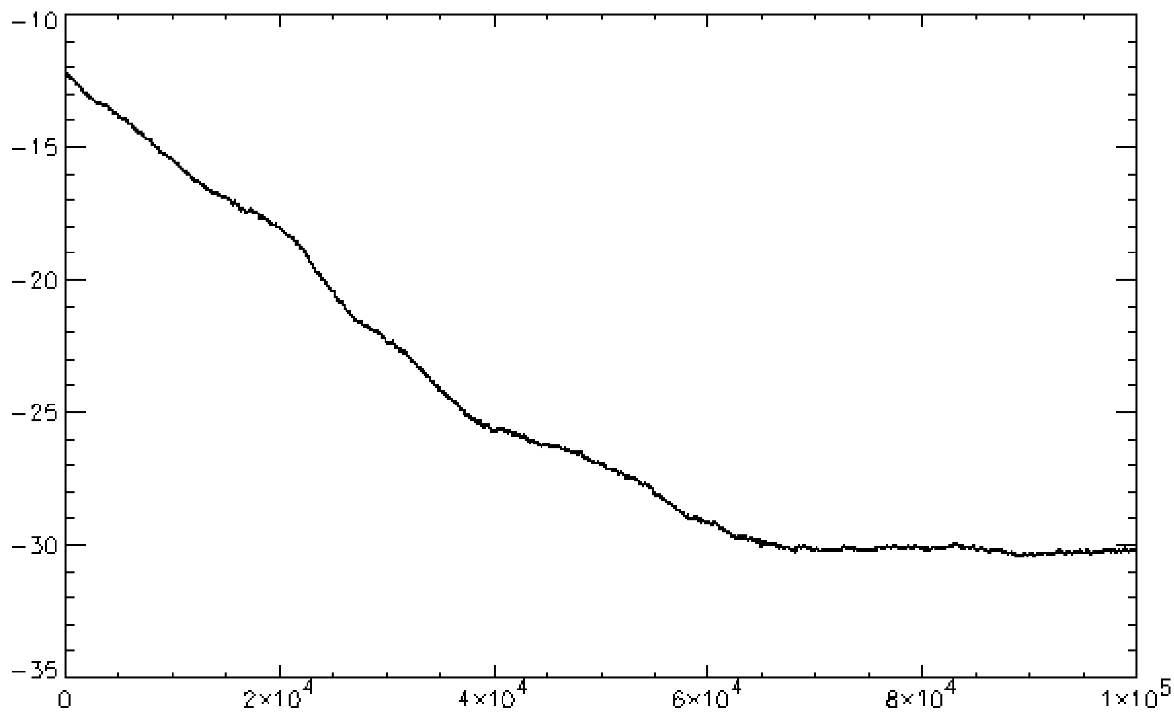
DP	Putty Time Tag	Correct Time
9460	38465.286	38465.286
9461	38465.395	38465.386
9462	38465.489	38465.486
9463	38465.598	38465.586
9464	38465.692	38465.686
9465	38465.785	38465.786
9466	38465.894	38465.886
9467	38465.988	38465.986
9468	38467.033	38466.086
9469	38467.033	38466.186
9470	38467.033	38466.286
9471	38467.033	38466.386
9472	38467.033	38466.486
9473	38467.033	38466.586
9474	38467.033	38466.686
9475	38467.033	38466.786
9476	38467.033	38466.886
9477	38467.033	38466.986
9478	38467.096	38467.086
9479	38467.189	38467.186
9480	38467.298	38467.286

This shows that there are no missing data points, but there are places where the time does not update. These are most likely these are caused by a data Tx failure when the mouse is being moved.

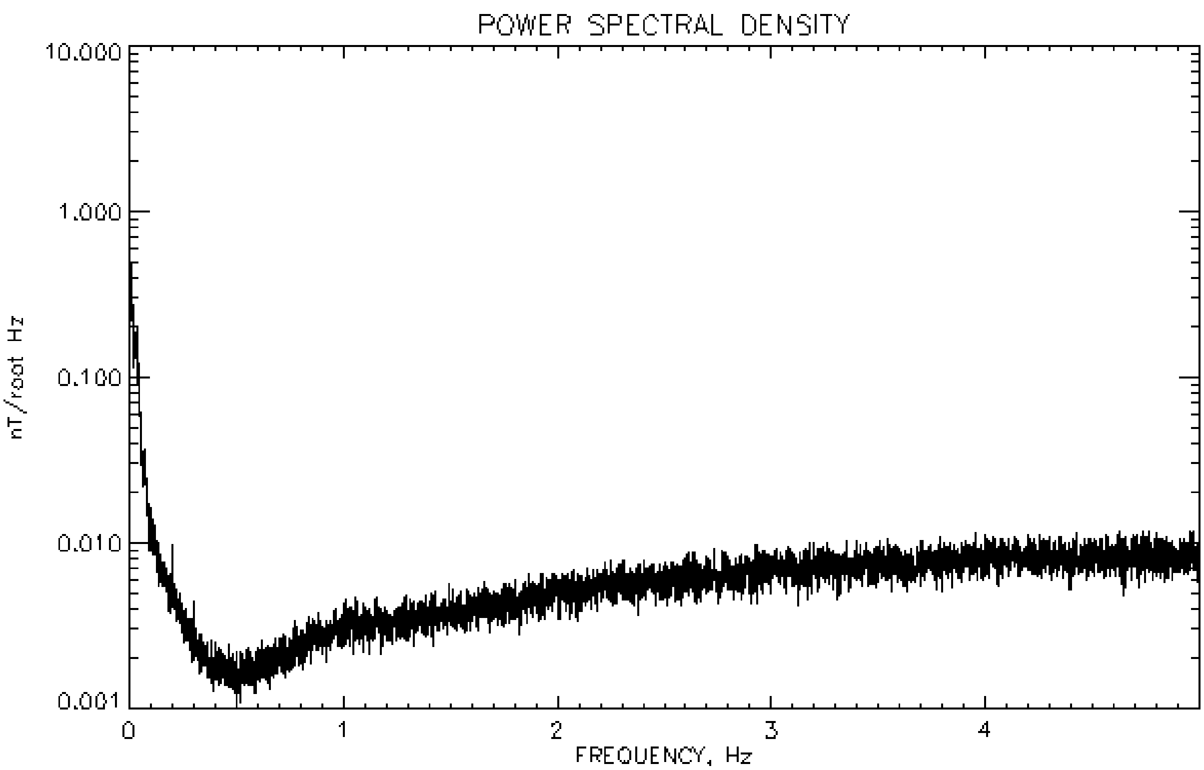
Here is a plot of the TF data where the DC has been removed. Two boats signatures are evident near DP 20000 and 45000.



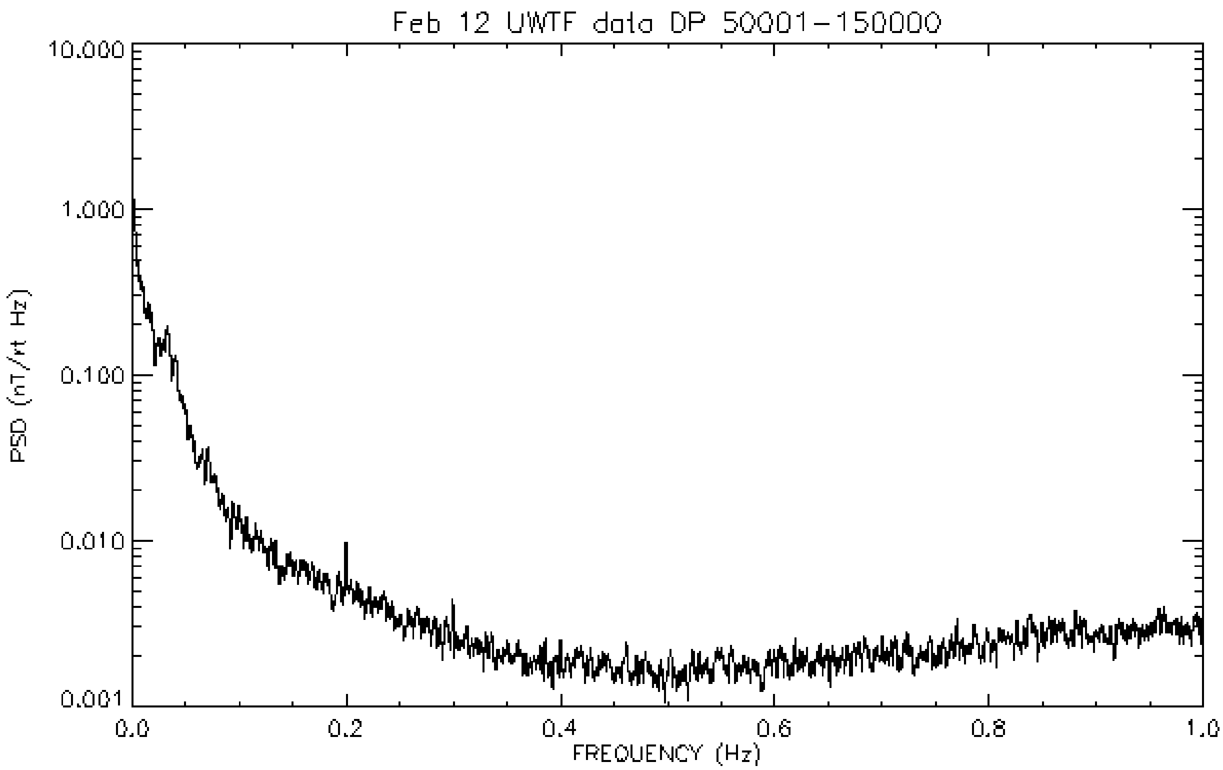
Here is a plot of the data from DP 50001:150000 (after the ship signatures). There is very little geomagnetic activity during this time.



And here is a plot of the PSD of the same data.



Here is a zoomed-in plot showing only the 0-1 Hz band



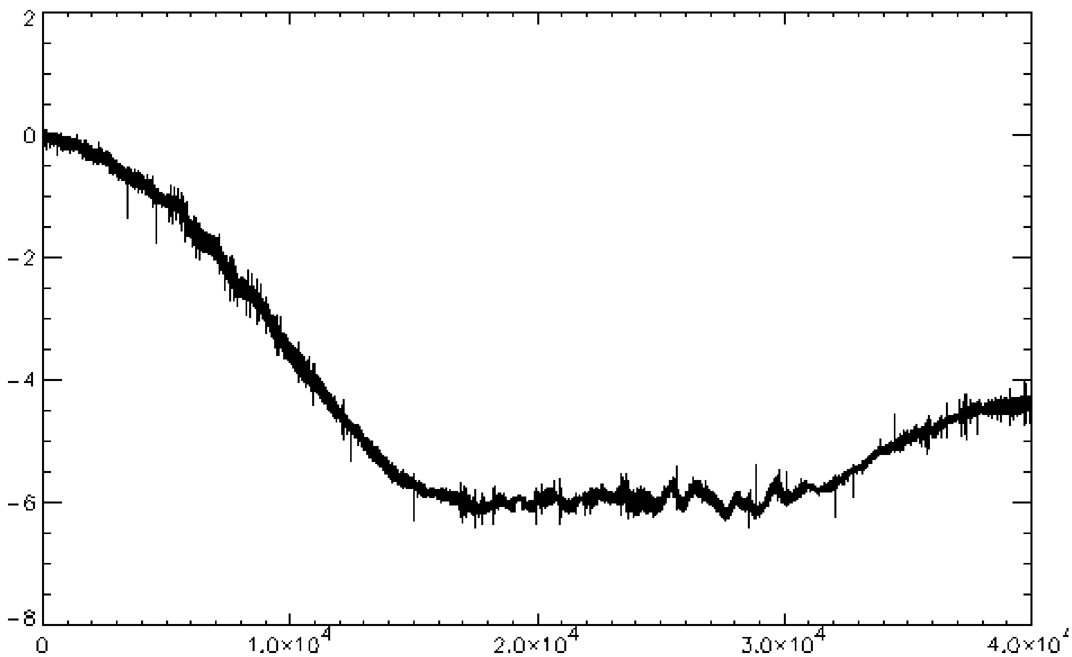
There are very small discrete lines near 0.2 and 0.3 Hz – suggesting the fundamental is actually 0.1 Hz but it is lower than the ambient field variations so it is not visible. However, these lines are very small and should not cause any problems with data analysis.

Appendix C: Feb 12 2015 basestation data

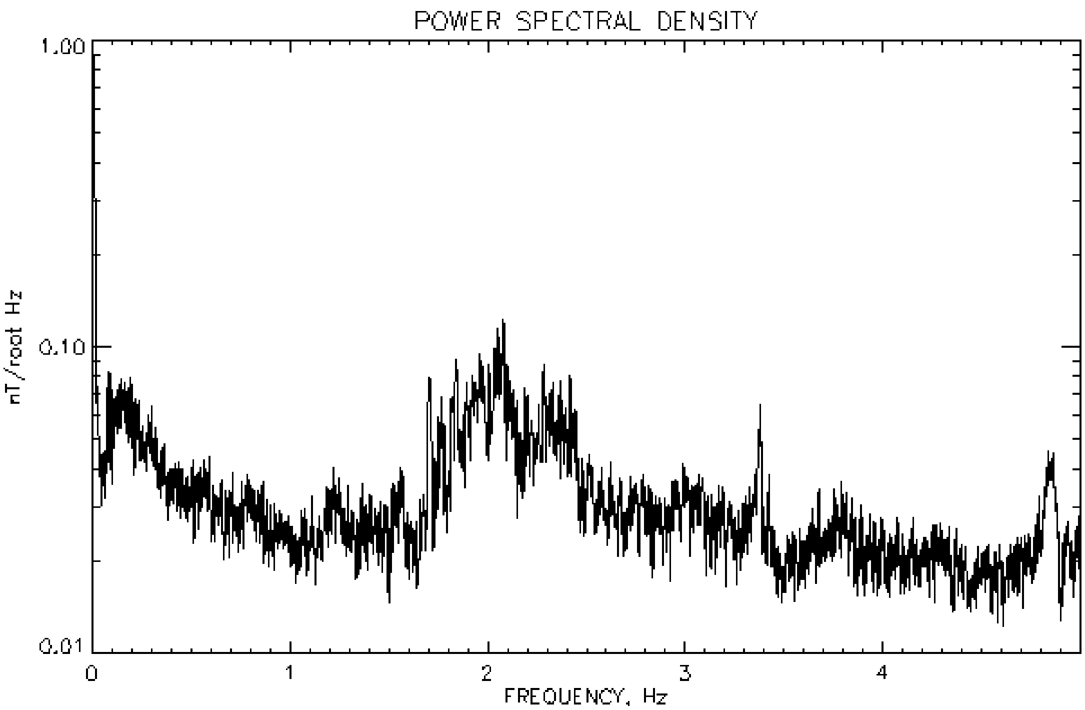
File = TOA5_56936_MagData_139.flagged (created by running the Campbell converter, then replacing “, :, -, with spaces. The NAN was set to 50000.000. All this was done with HxD.exe)

Use IDL routine ftlauderdale_Feb_2015.pro to read in the data, change the 50000.000 values to the previous value, and then make some plots

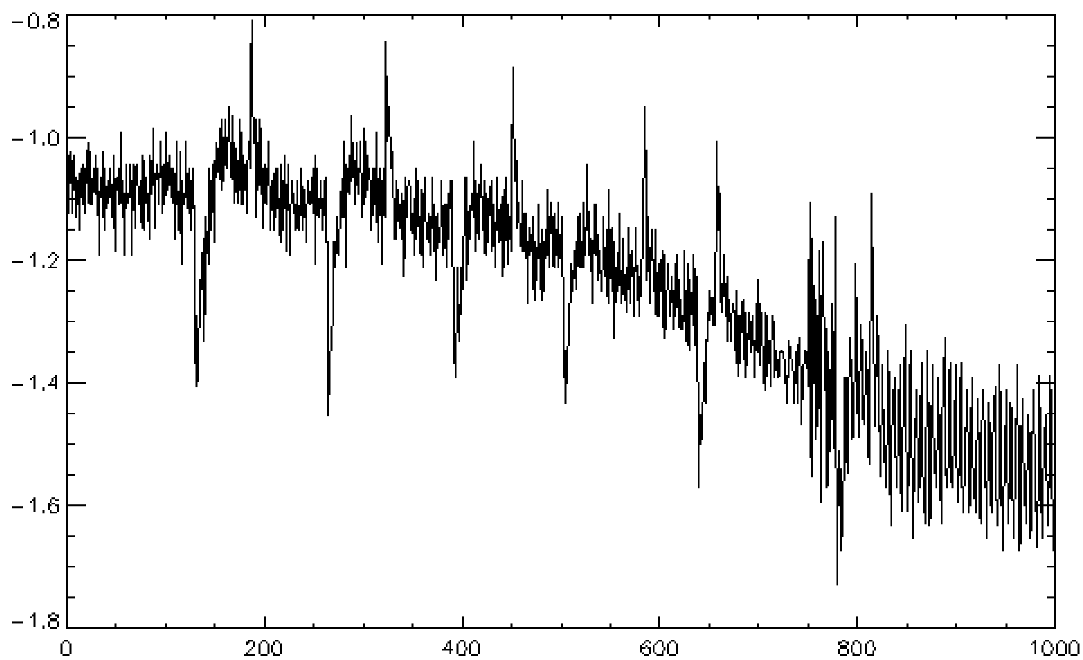
Here are the first 40000 data points with the DC removed.



And here is the PSD from those 40000 points



The noise level is now ~ 20 pT/√Hz which is about 20 x the sensor noise level. There are also discrete frequencies and either a resonance, or a moving line as was seen in the Nov 16 2014 data.
Here is a close up of the noise behaviour at just dp 5000-6000:



DP 5000-6000 showing types of noise behaviour. (DC removed)

<u>Conclusion:</u> The magnetometer is most likely failing as this behaviour is not normal. The G823 should be returned to Geometrics for repair.

Appendix D: Analysis of undersea and shore magnetometer data from SFOMF 4-7 Sept 2015

Executive summary

The following problems were identified with the underwater and on-shore TF data:

- extra headers and the lack of LF CR at the end of each line in the undersea made the data difficult to read into IDL. This was corrected using an ASCII editor but it would be much better to change the format of the recorded data.

- the undersea data contained many smaller glitches that had to be corrected by hand. It also contained many "odd" features that didn't correlate with the on-shore geomagnetic data. While it is possible that there are in fact oceanographic signals, the fact that a spectrogram of the data show a strong periodic behavior suggests that they are actually an artifact, not oceanographic signals. Possible explanations are:

1) movement of the mounting structure, especially if the mounting structure has magnetic components.
2) motion of power cables carrying current to the underwater sensors
3) operation of the ADCPs as they are nearby
4) noise from the G823 electronics as they are nearby. This is less likely that the other mechanisms because tests on data collected in Feb 2015 with the G823 sensor at the same depth, but with no ADCP nearby, did NOT show these features.

Note: Further analysis of the spectrograms of Sept 4, 5, 6, and 7 underwater TF showed that these odd features stopped at the same time (~ 20000 seconds UTC) and started up again (32000 seconds UTC) on each day. This STRONGLY suggests that none of the above mechanisms are responsible for the odd features.

- both data sets contained a few large amplitude, short duration transients. These transients were always offset of 3.3 seconds in the two data sets, suggesting that one of the time-stamps was incorrect. These large transients had a different shape in the air and in the water, but the rise time on the underwater signal was still so fast (1 sample) that it seems unlikely that it is an external field penetrating 259 m of sea-water.

- the origin of these large transients that can be seen in both the undersea and on-shore data is unknown, but the only possibility that we can come up with is a lightning strike into the water .

The following sections describe how the above conclusions were drawn.

1. Undersea data from Sept 7

1) The data files appear to be appended and each time it writes out a header with:

=~=~=~=~=~=~=~=~=~=~=~= PuTTY log 2015.09.03 17:53:20 =~=~=~=~=~=~=~=~=~=~=~=

This makes parsing a bit tricky.

2) The time stamp is written twice as follows:

15 09 03 17 02 43 668 $ 44264.894,1741
15 09 03 17 02 43 668

If it wasn't for the extra headers, it can be read with IDL procedure dfordPutty_FtLauderdale.pro.

3) I simply used HxD to search for and remove any lines with "Putty"

4) save it to 20150903_MAG_LOG_UTC.bak

Solution to avoid extra headers: Don't append files.

5) The procedure dfordPutty_FtLauderdale.pro appears to skip lines so that the sample rate is coming up as 5 Hz, not 10. Using HxD.exe to display the data it was determined the data actually has:

15 09 03 17 02 43 668 $ 44264.894,1741 CR
15 09 03 17 02 43 668 LF

Instead of

15 09 03 17 02 43 668 $ 44264.894,1741 CR LF
15 09 03 17 02 43 668 CR LF

I corrected this using HxD.exe and saved the file to 20150903_mag_log_utc_cor.txt

It now reads correctly and the time increment between data points is 0.1 seconds with some jitter on it just as we would expect.

6) Look at the start and end time and the number of data points in test.txt:

At dp 312280, time =0.034 and at dp 1176331, time =0.037

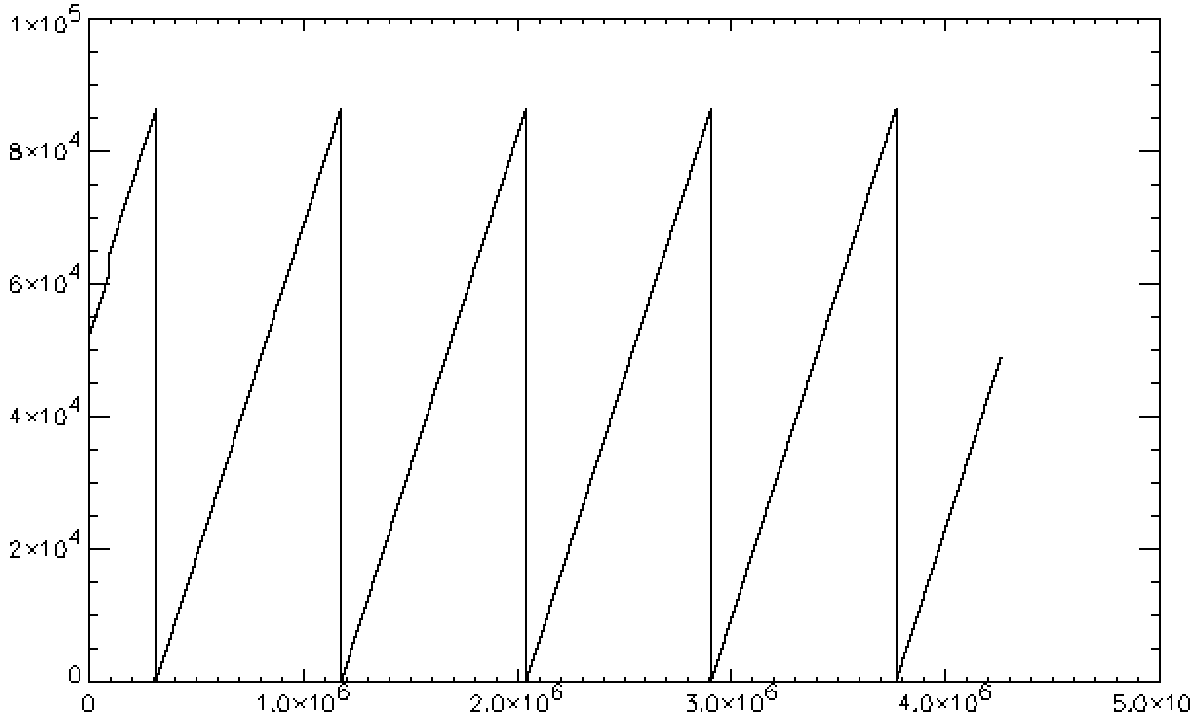
Delta DP = 1176311-312280 = 864051 dps

Deltatime = 86400.003 seconds

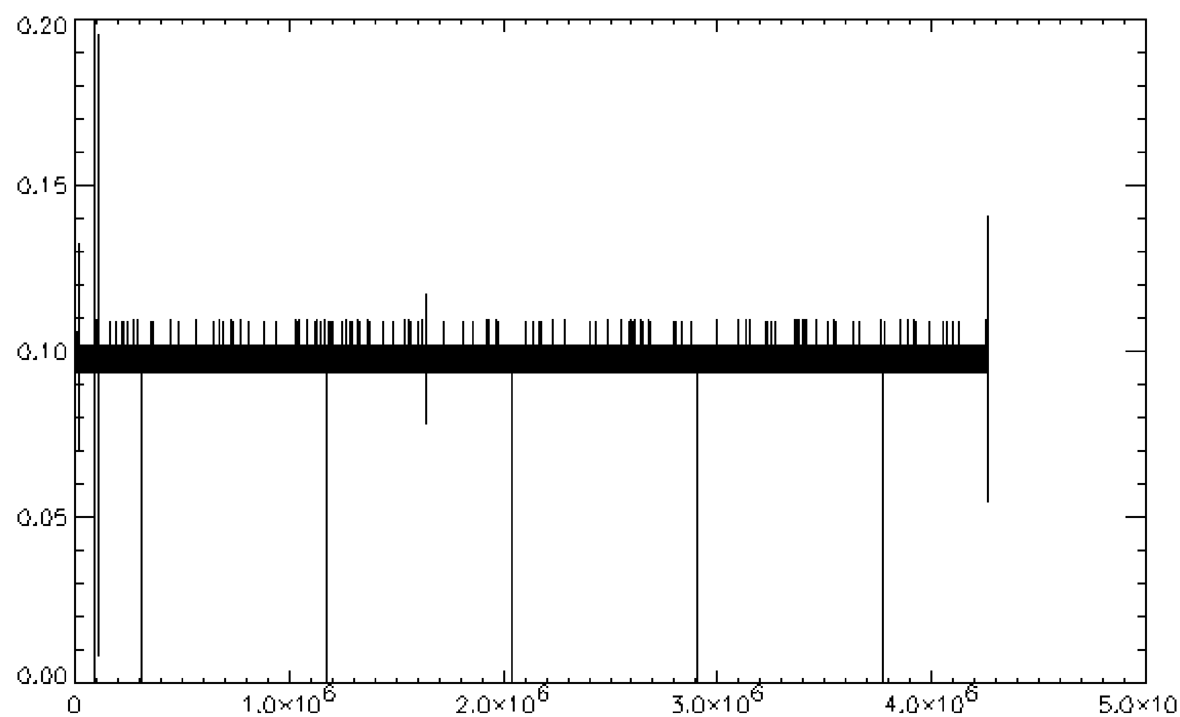
Conclusion SR = 10.0006 Hz

While this is almost 10 Hz, it will be necessary to convert to EXACTLY 10 Hz for both the undersea and shore TF.

The following figure shows the time series plot for time.

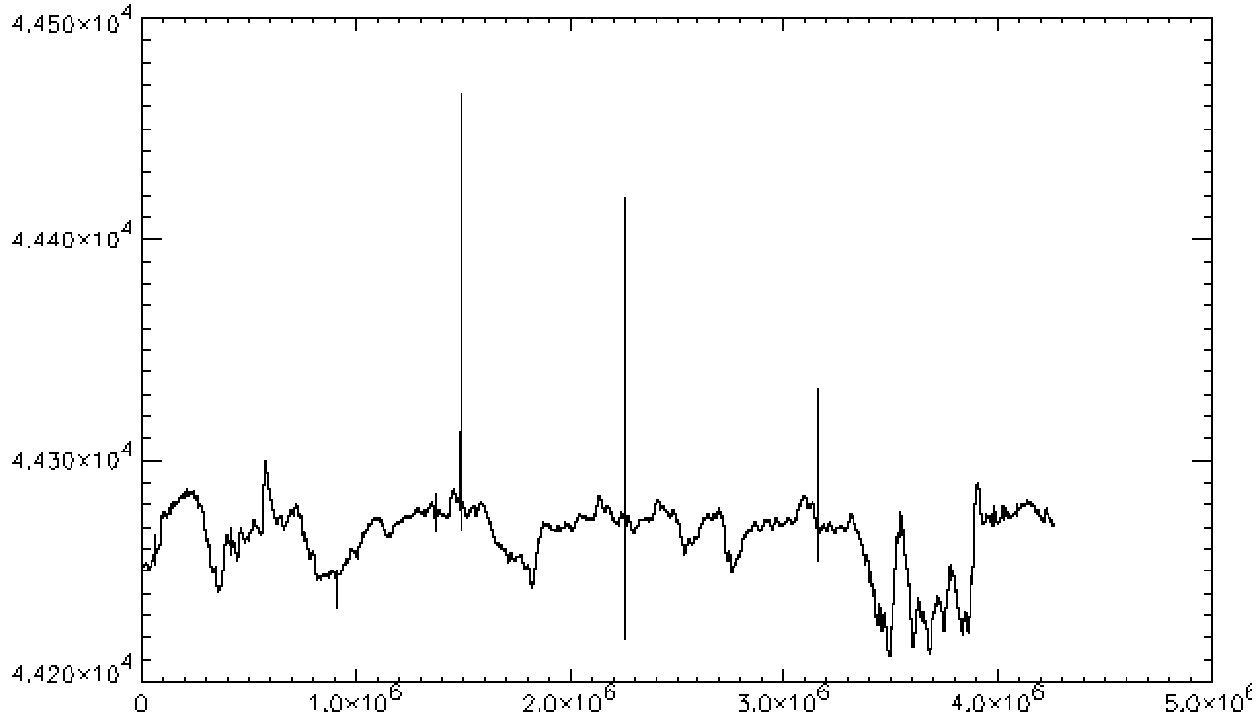


Note there is a discontinuity in the time data for the first day, but that corresponds to the place where there was an extra header in the (appended) data file. Here is the derivative of time:

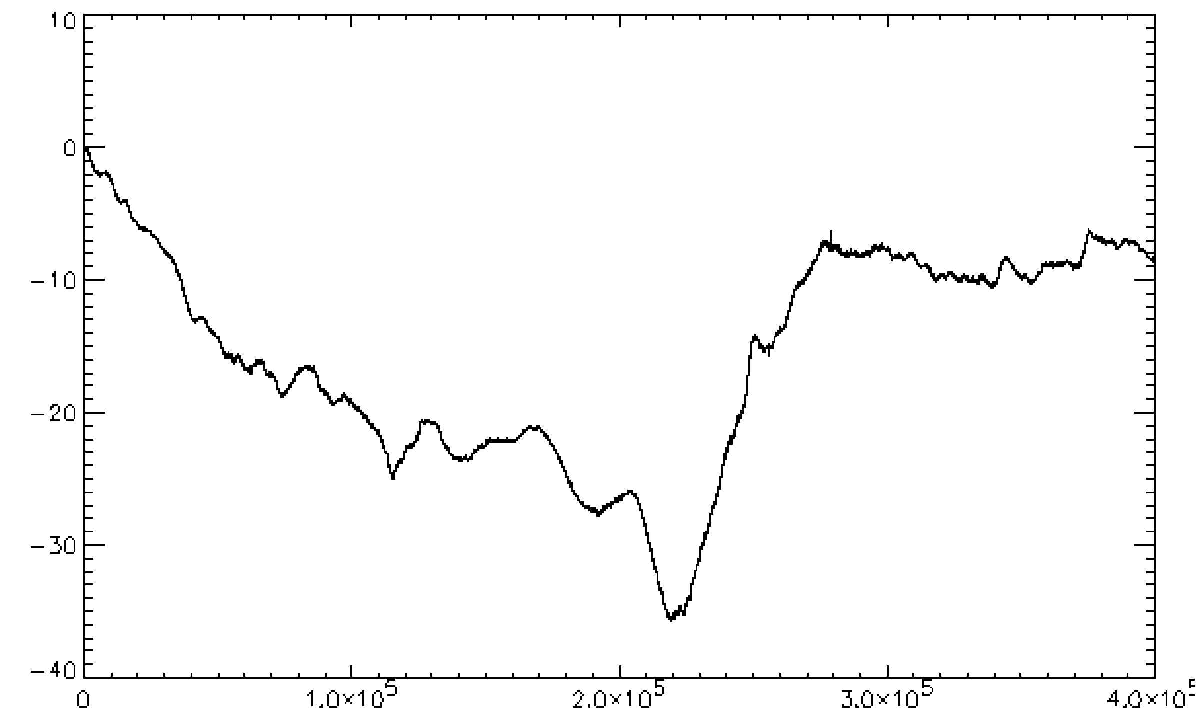


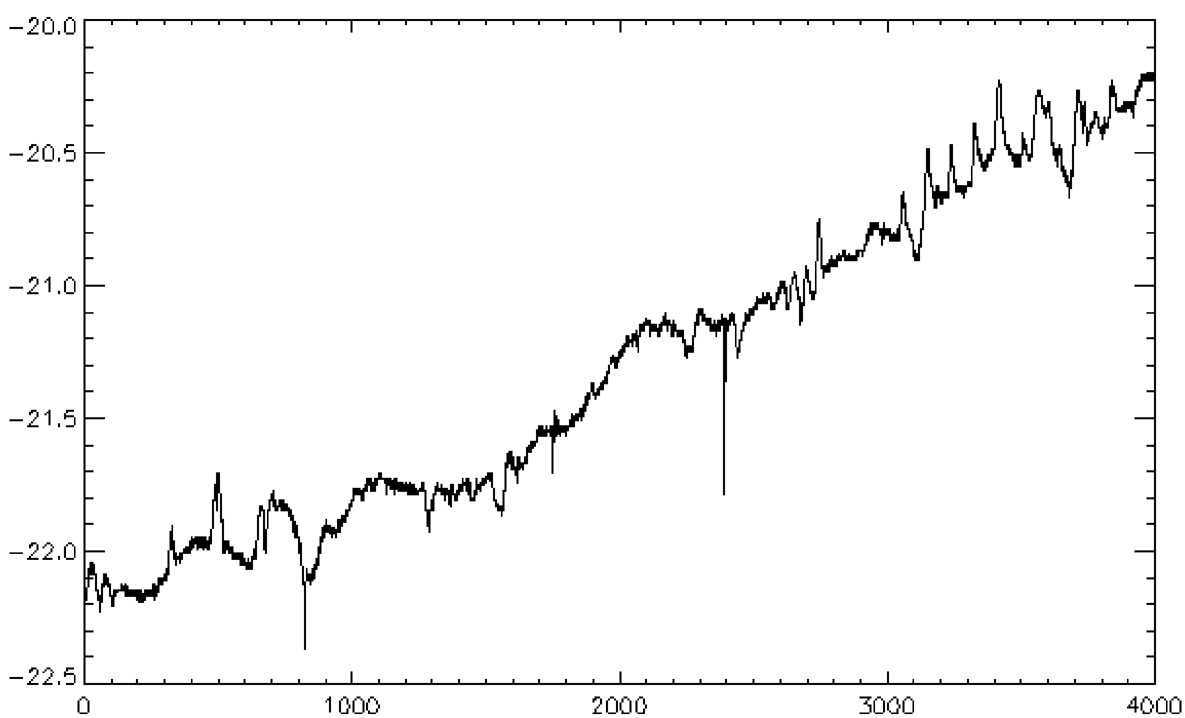
The large negative spikes correspond to the roll-over from one day to the next. The spikes at the beginning are due to the discontinuity in the data file. The apparent high values at 0.11 are most likely just jitter in the time-tagging on the data acquisition system. There does appear to be one odd artifact near dp 1,600,000 but the spike is symmetric about 0.1 so it doesn't appear to be a missing (or extra) data point.

The following figure shows the time series plot for the magnetometer.



The spikes are actually ship signatures. The discontinuity near the beginning is due to the time gap where the file was appended. The next plot shows the region between dp 1,600,001 and 2,000,000 where there are no ship signatures. The DC value has been removed to better see the variation.

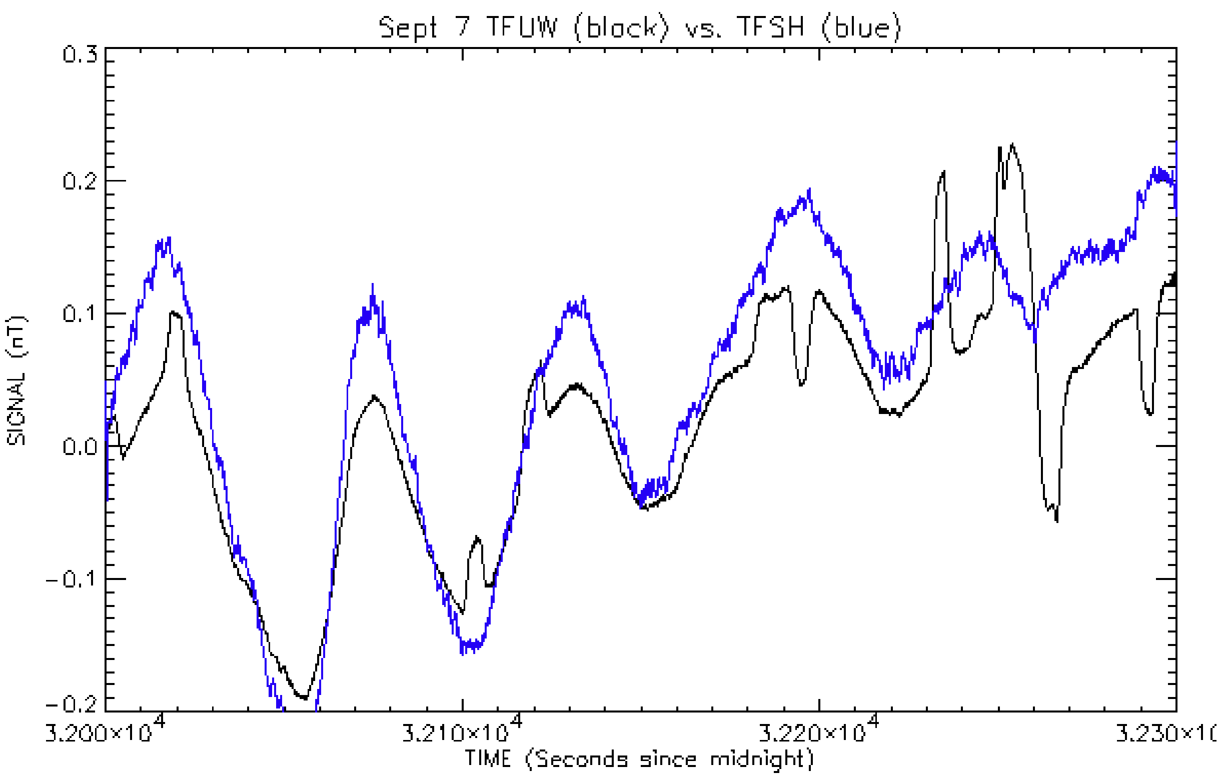




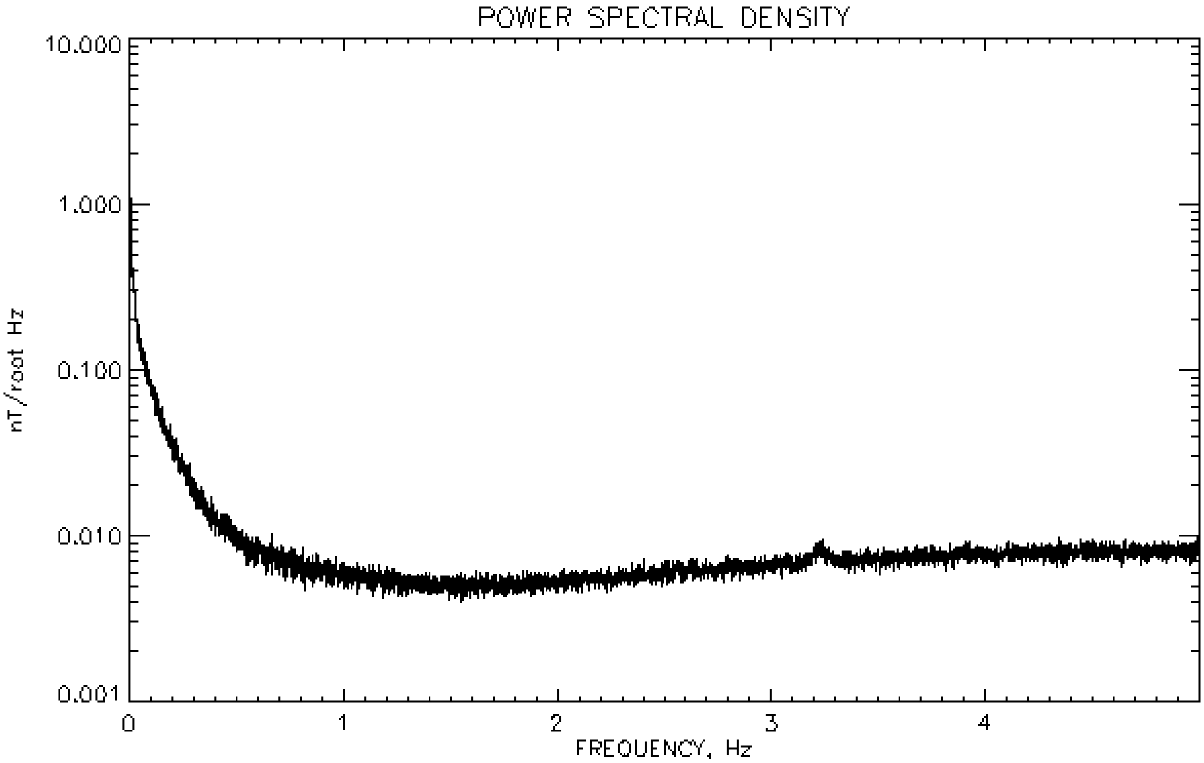
Zooming in on the region 1,841,000 – 1,841,000 shows some small very sharp transients that only last a few data points. These are not likely due to oceanographic features, nor are they occurring at uniform intervals so they are most likely not due to the ADCP interference. The above plot, along with the next one, also shows some "odd" features in the time series – anomalies that last 10-20 seconds, have quite sharp rise and fall times but aren't pure step functions, and have amplitudes of ~ 0.2 nT. These anomalies are not present in the shore station data so they are not geomagnetic in origin. It is conceivable that they are oceanographic in nature, but they do not have the "packet-structure" that we have seen in the past for oceanographic signals.

Other possible explanations are:

1) movement of the mounting structure, especially if the mounting structure has magnetic components.
2) motion of power cables carrying current to the underwater sensors
3) operation of the ADCPs as they are nearby
4) noise from the G823 electronics as they are nearby. This is less likely that the other mechanisms because tests on data collected in Feb 2015 with the G823 sensor at the same depth, but with no ADCP nearby, did NOT show these features.



The following plot shows the PSD of the magnetometer data from dp 1,600,001-2,000,000 which does not contain any ship signatures.



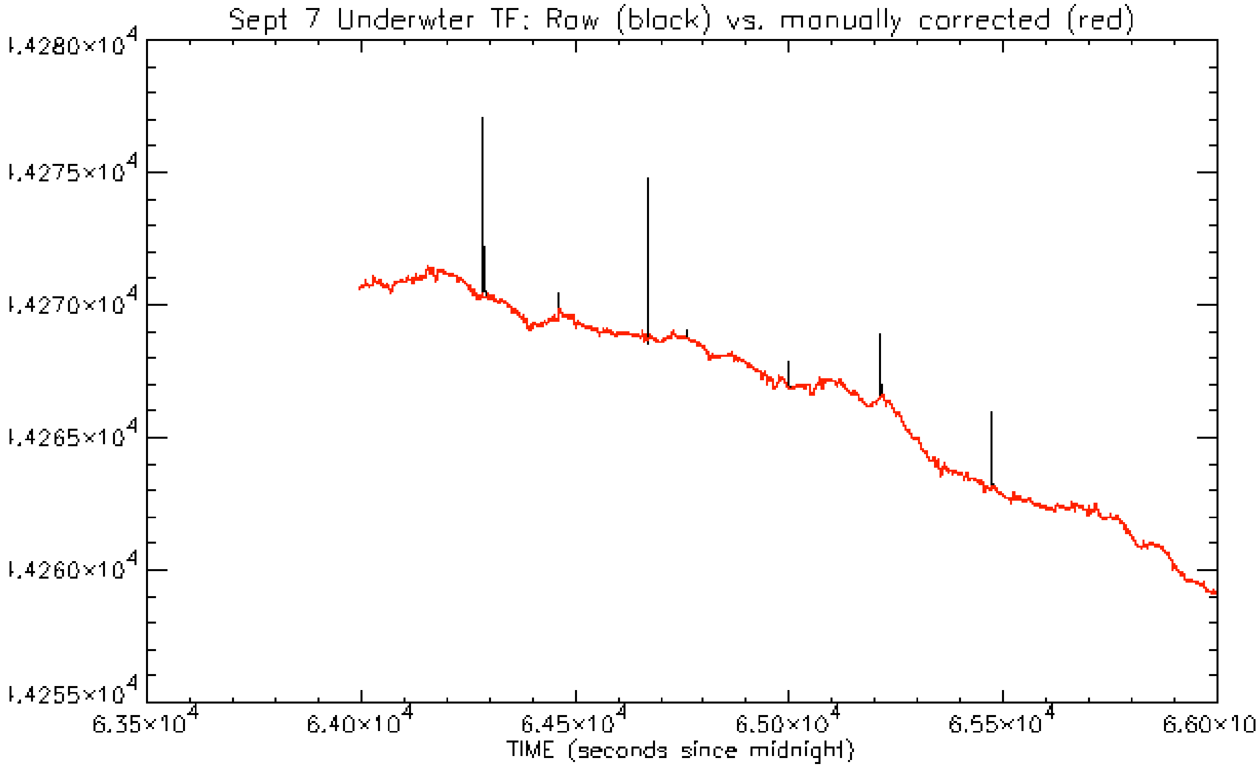
It is increasing slightly towards the high frequency, and the lowest noise a few pT/√Hz, both of which are consistent with typical G823 noise characteristics.

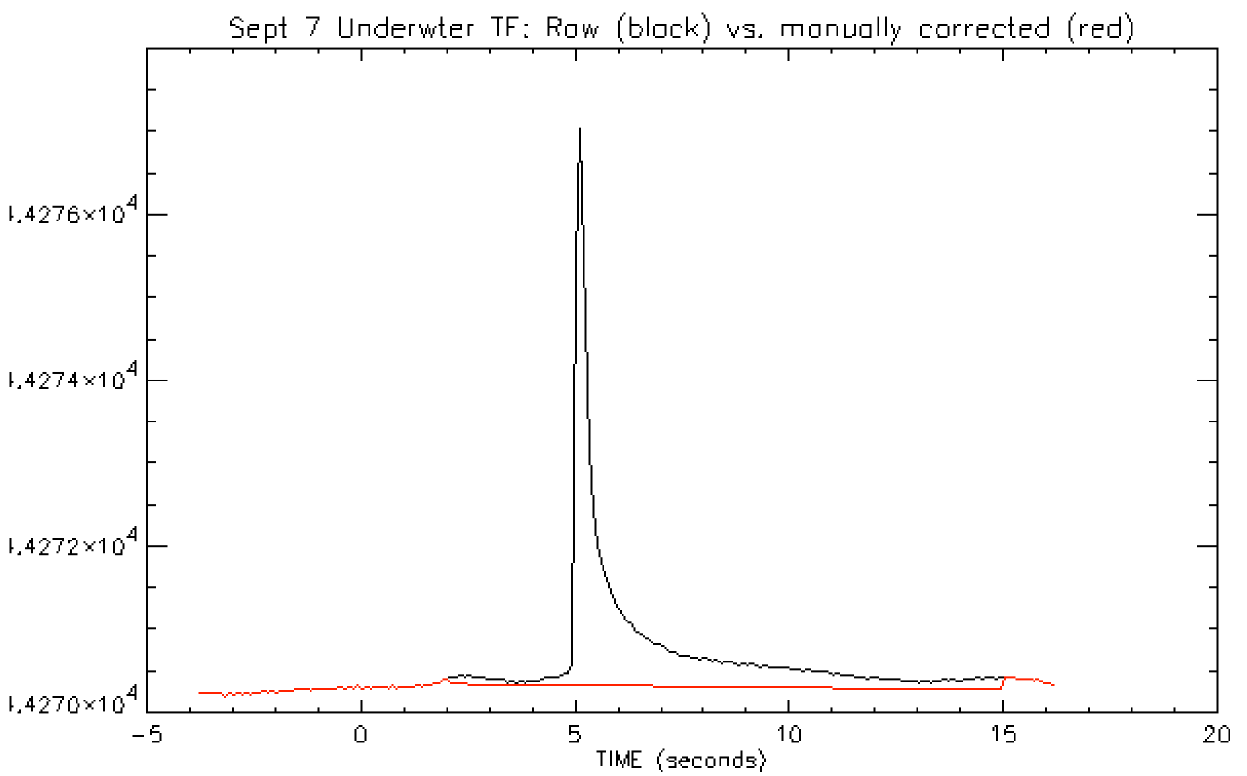
Created 20150903_mag_log_utc_cor.fld with YY, mm, DD, seconds since midnight, TF.

2. On-shore Data

The on-shore data contain some very large, very short duration transients and some smaller amplitude transients. Note these smaller transients were seen in the data that was analyses in Feb 2015 and the conclusion at that time was that the shore station location was actually quiet noisy. Those small amplitude transients were seen on two magnetometers and were extremely coherent, indicating they were real magnetic fields not sensor errors.

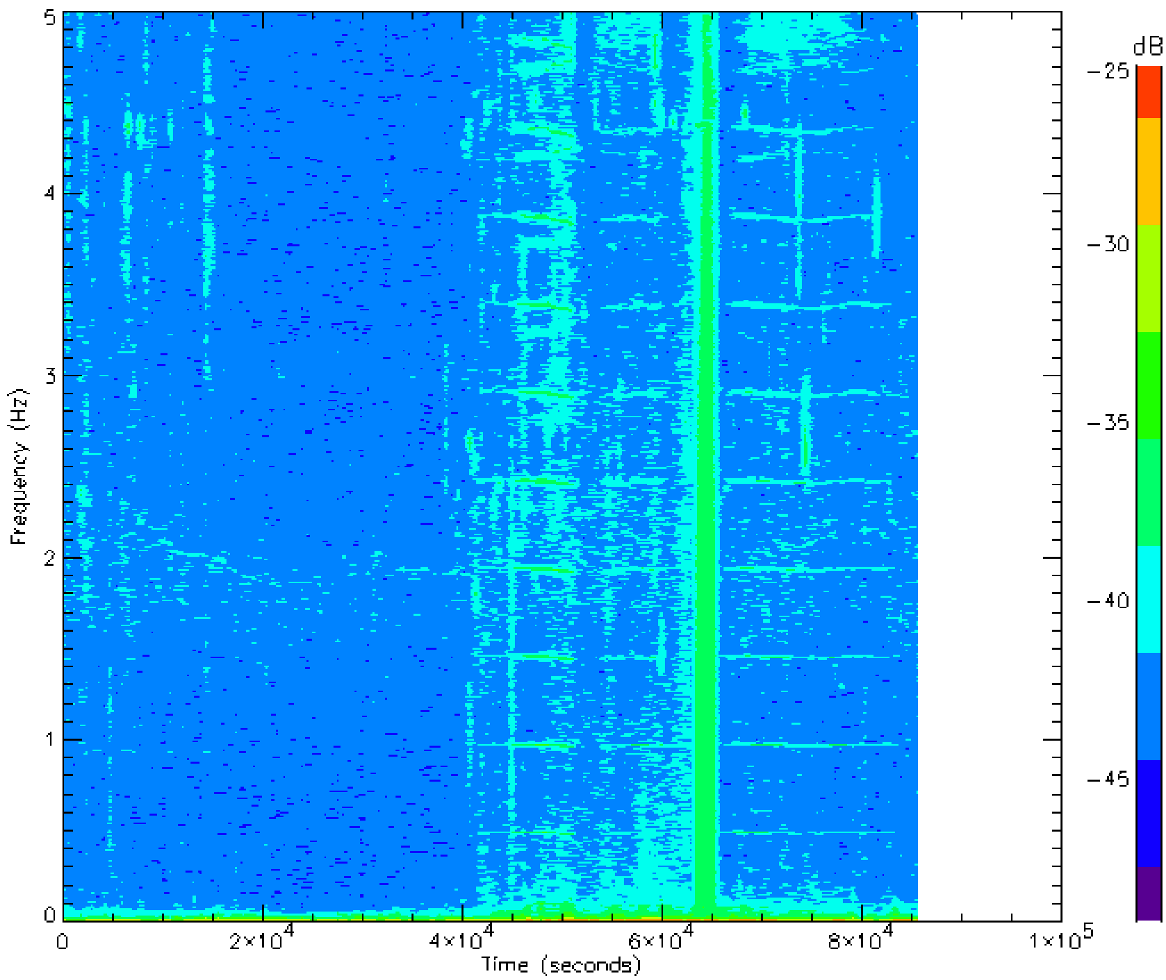
The following plot of the transients in the Sept 7 portion of the data shows the original transients (black), and the data with those transients manually removed for further analysis (red).





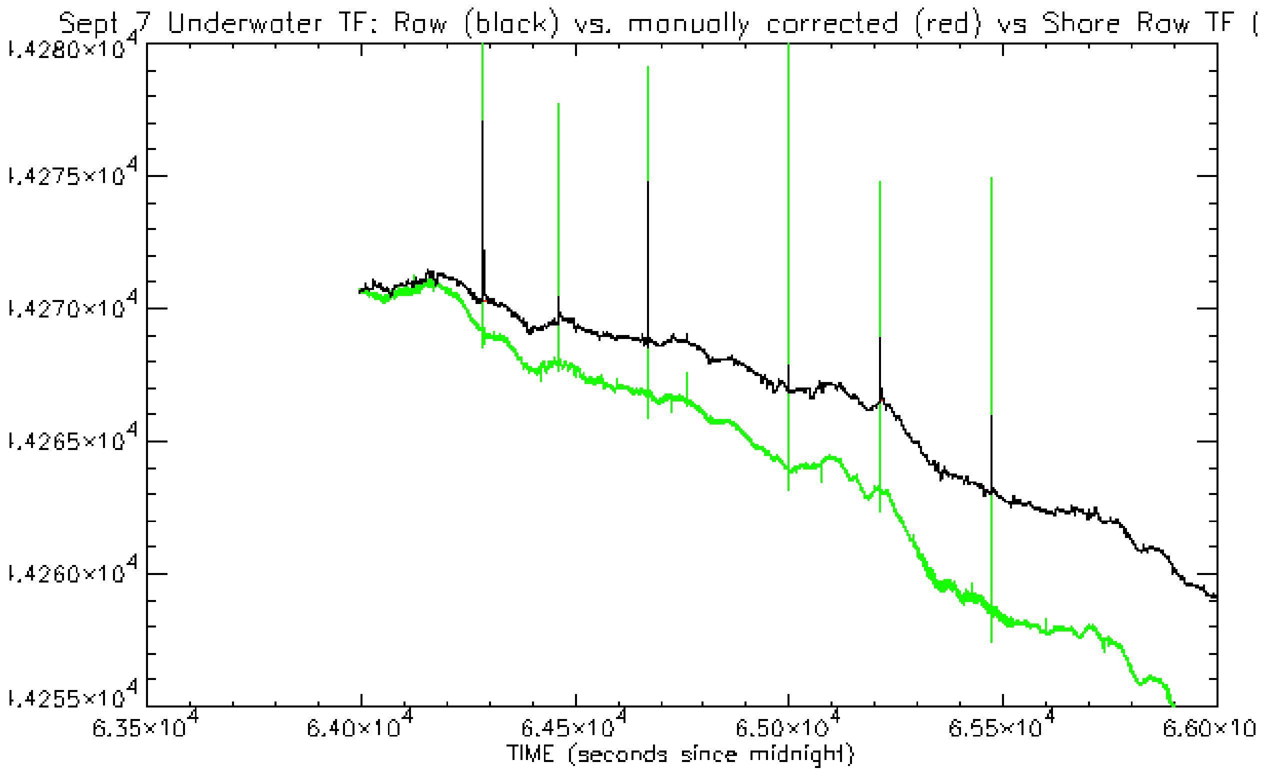
As you can see the transient only lasts a few seconds.

The following plot shows a spectrogram of the Sept 7 on-shore data after the spikes were removed. Clearly there is a very large harmonic source that turns on at about 40,000 seconds. This is consistent with the type of noise that was seen previously in the Jan 7 2015 data set where it was determined that the basestation location was very noisy.



3. Comparison of undersea and on-shore TF data for Sept 7, 2015

If we compare the underwater and shore Raw TF for the area with the large transients, we get:

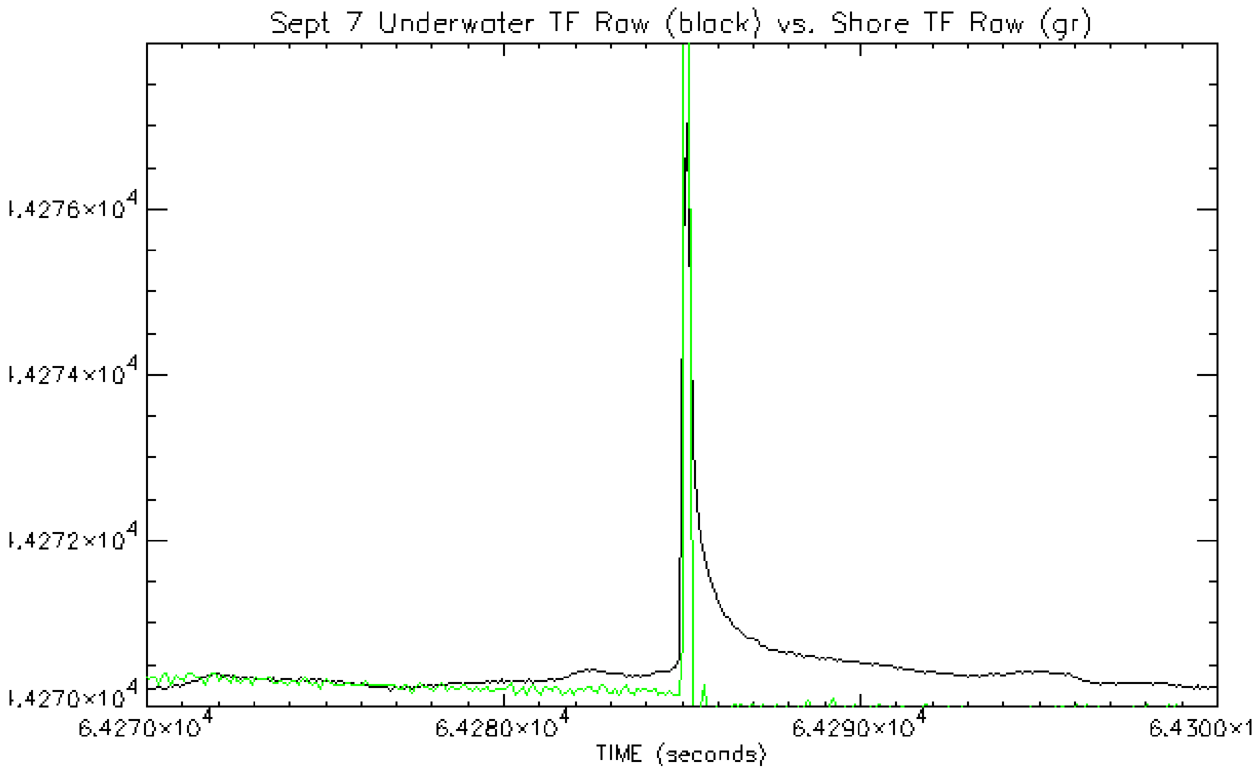


Strangely enough, these transients show up in BOTH the undersea and shore data. A close examination showed that there is a consistent 3.3 second difference between the undersea (black) and on-shore (green) spikes. This delay also seemed consistent with what were clearly geomagnetic signals. For the rest of this analysis:

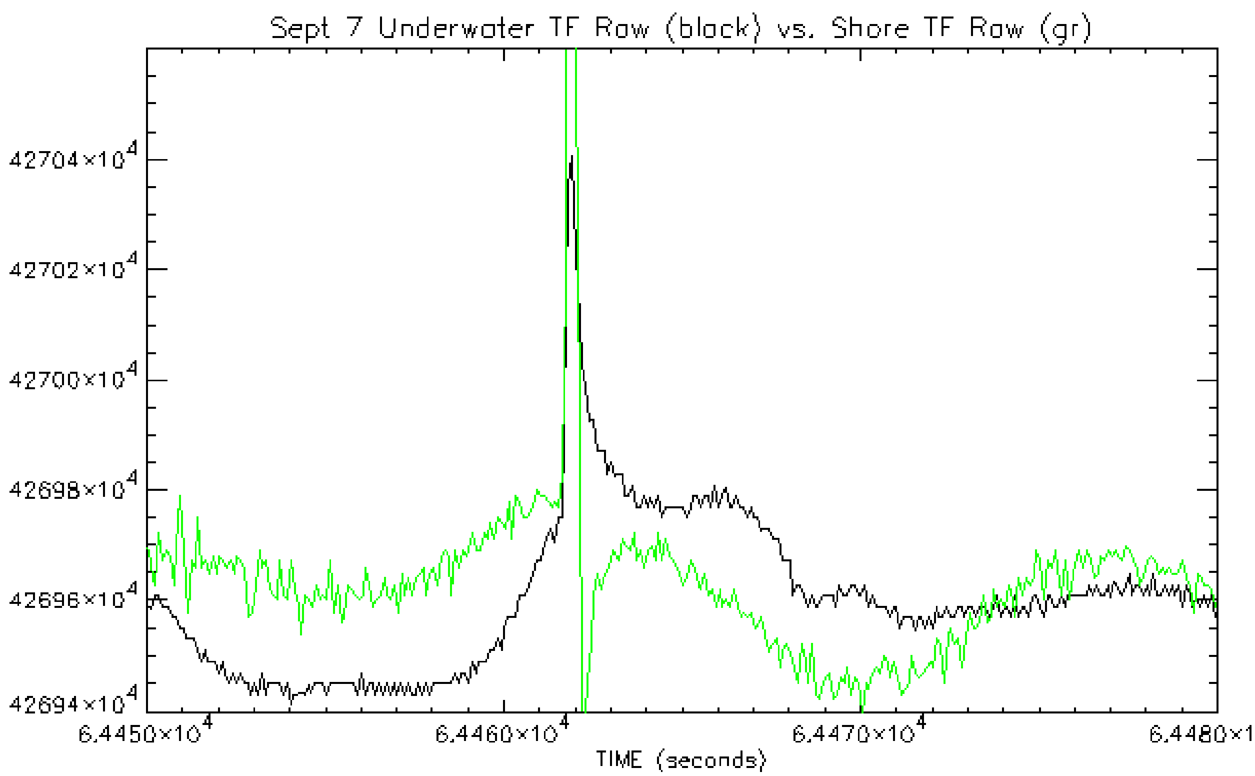
Time on-shore = time-onshore -3.3 seconds. Note however it could be the off-shore data that is wrong by +3.3 seconds and it is entirely possible that it is the latter. As both systems are supposed to get their time from a GPS-locked time server, the source of this time error is not understood.

<u>4. Question: What is the source of this 3.3 second error (is a computer clock not getting synchronized to UTC often enough?)</u>

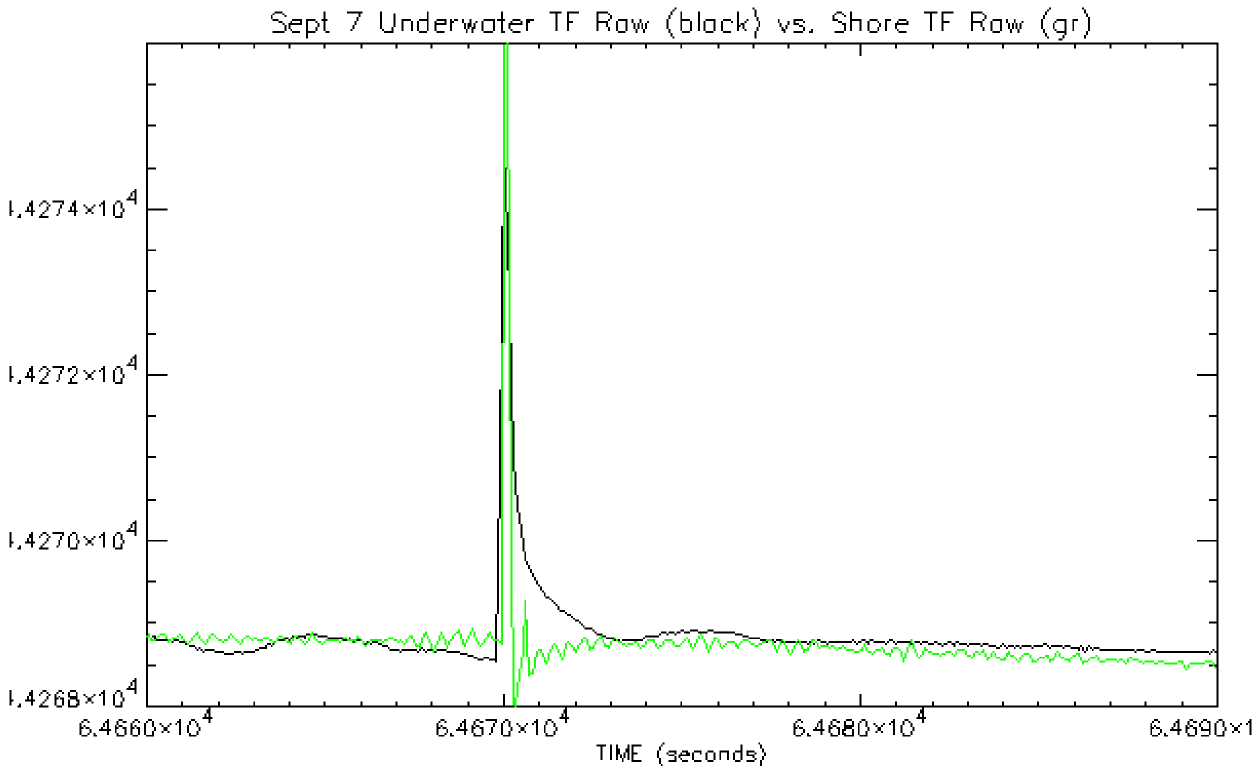
Here is a close-up on the first spike on both systems, after the 3.3 second correction:



And the second spike



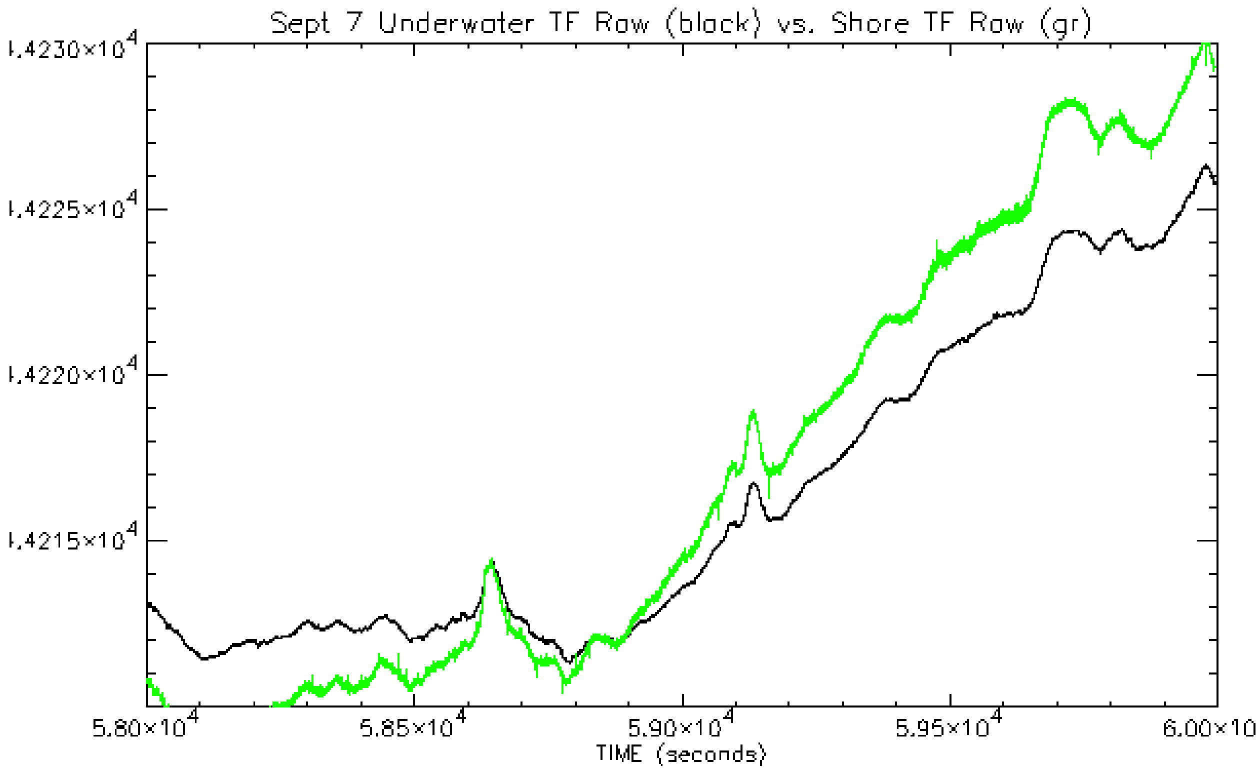
And the third spike



This clearly shows that the on-shore spike is a very fast transient (< 1 second), but the undersea spike has a noticeable decay over several seconds.

Conclusion: This might be consistent with a very large external field and the shielding effect of the water causing the change in shape and amplitude of the field at the sea-bottom. Could this possibly be a lightning strike hitting the water?

In addition to these big glitches in the shore station data, there are many smaller, very short duration spikes that do not appear in the undersea data. The following plot demonstrates this.

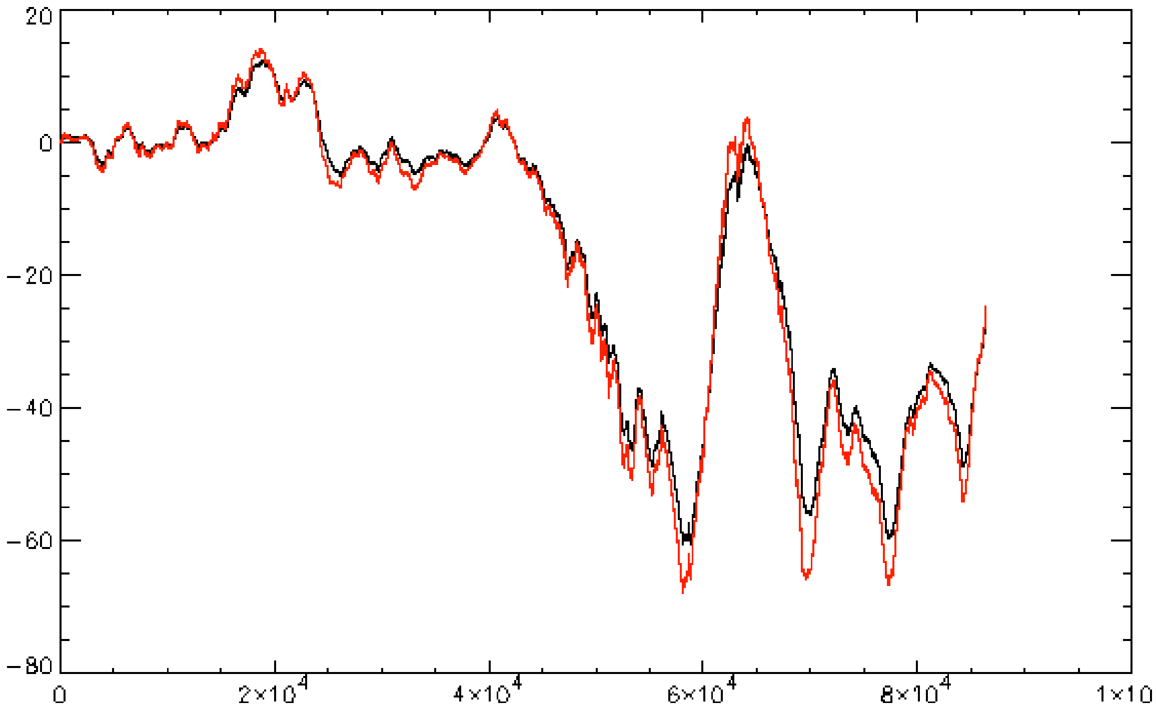


These spikes are consistent with the glitches we saw in the data from two basestation magnetometers in January 2015 data, which indicates that the shore station simply is not set up at a very quiet location.

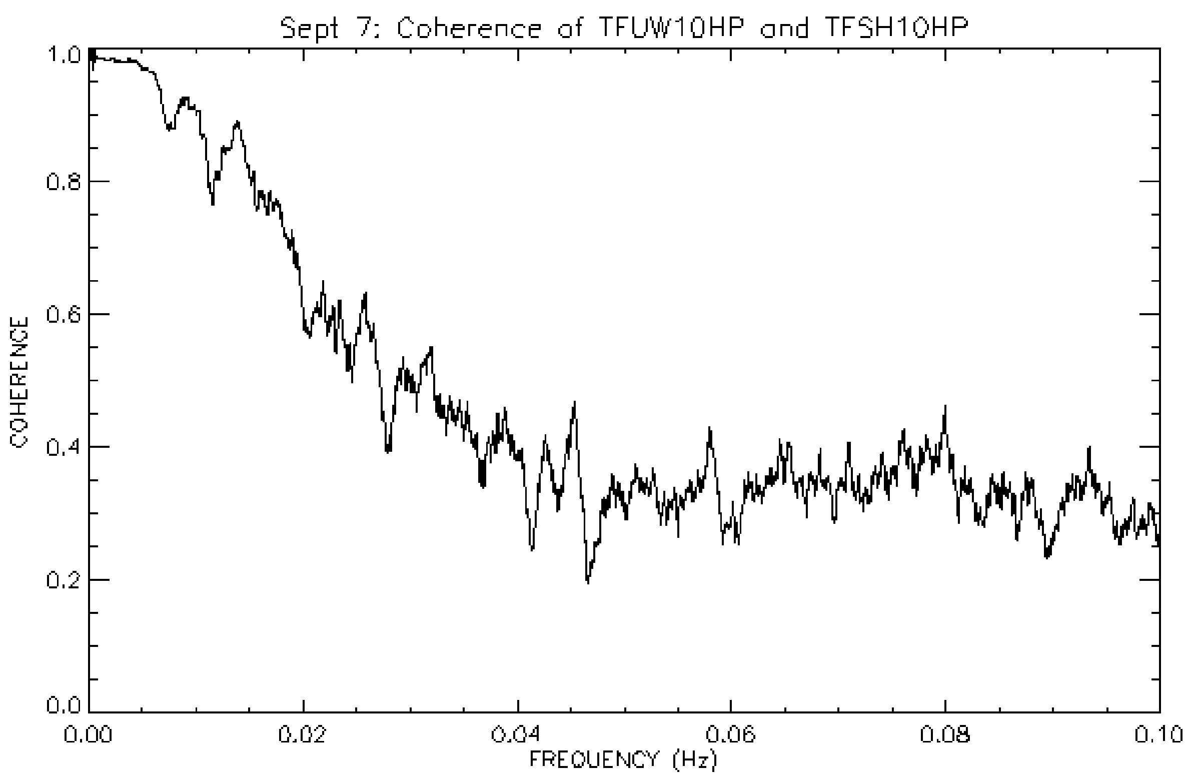
5. Noise reduction using the on-shore data

The transients and spikes from both data sets were removed.

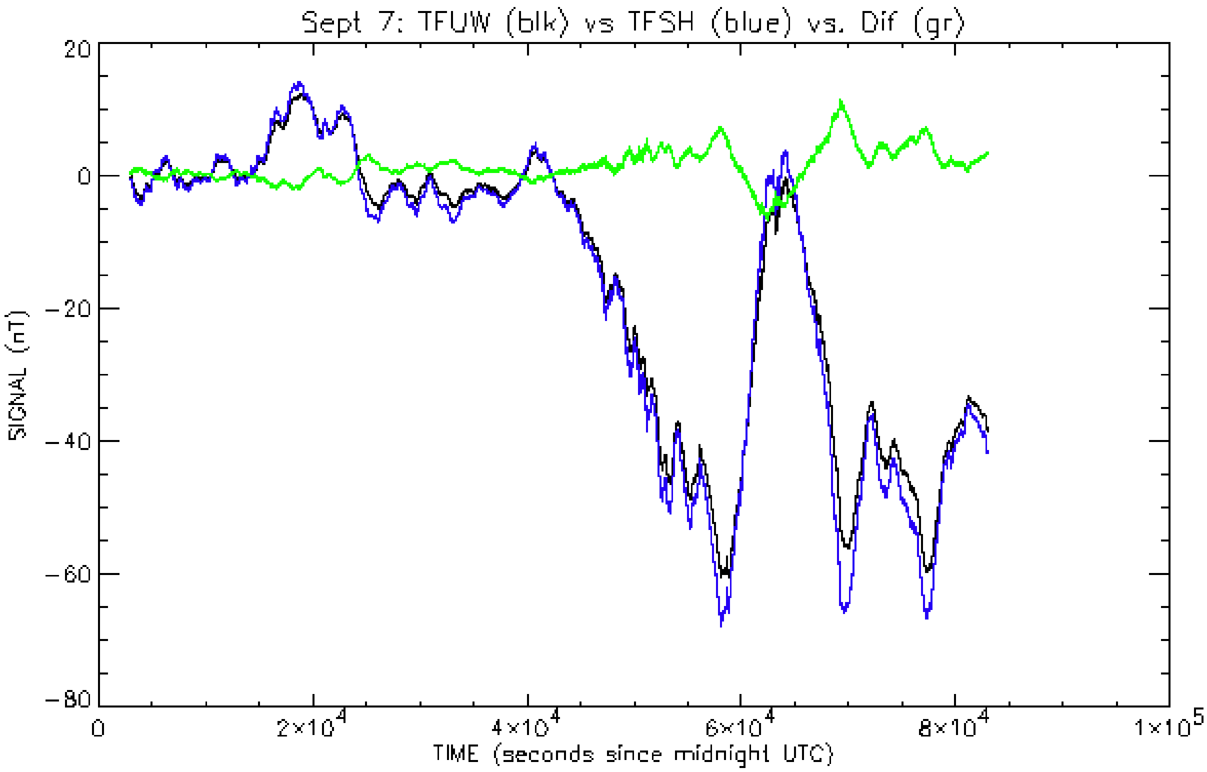
Here is a comparison of the entire data sets from Sept 4-7, 2015 (black = undersea and red = shore)



After re-sampling to exactly 10 Hz, and filtering with a 0.001-1 Hz band-pass filter, and skipping the first 30,000 dps to avoid ringing, here is the coherence:

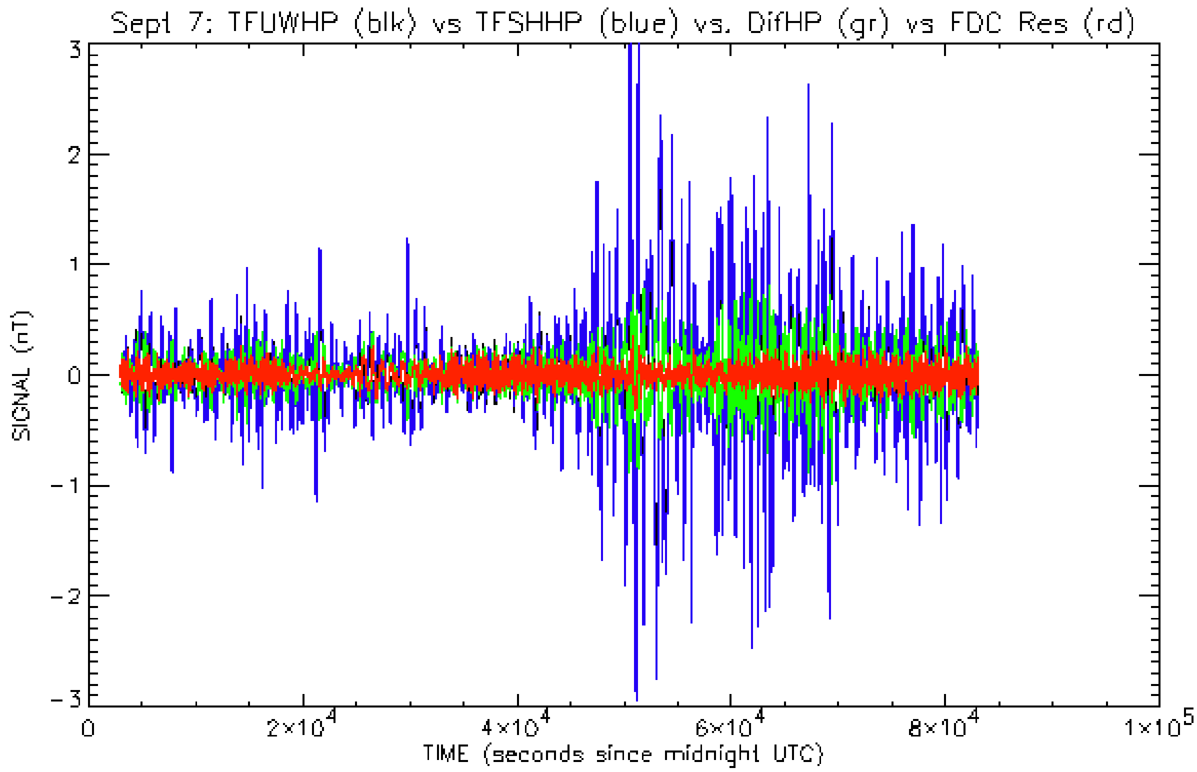


Here is a plot of the time-aligned undersea (black), on-shore (blue), and difference signals (DC removed).

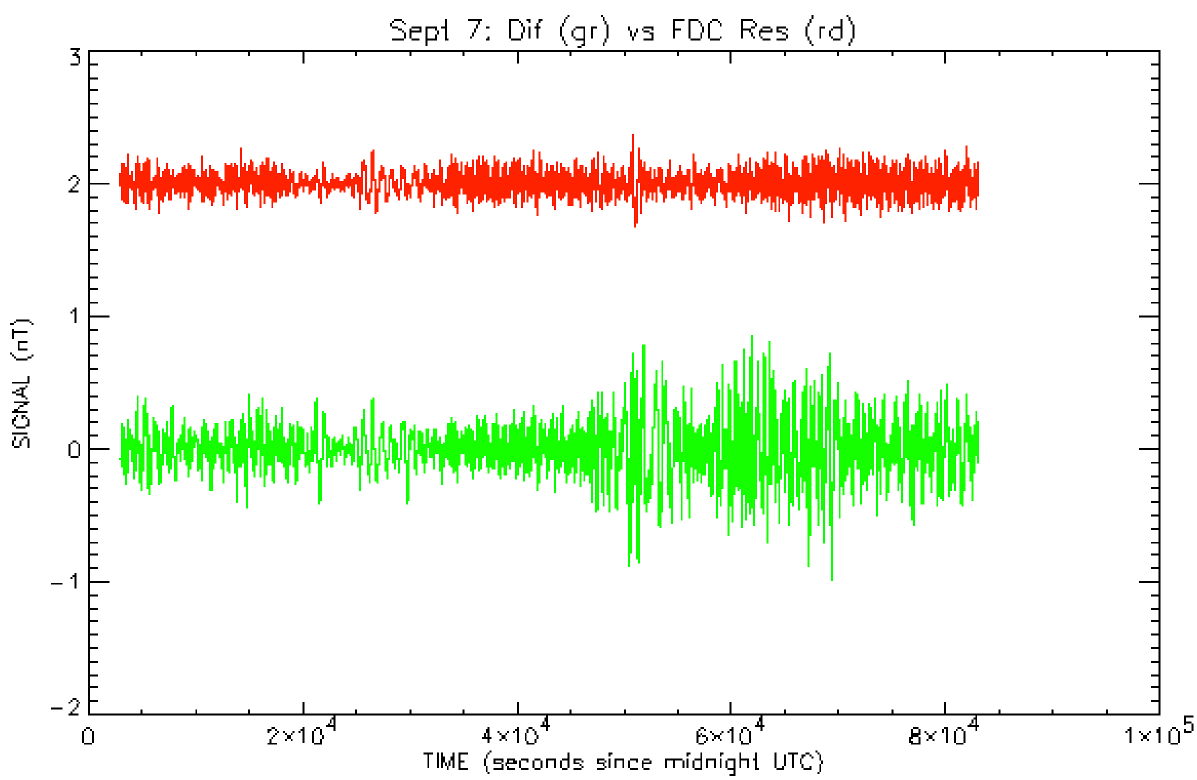


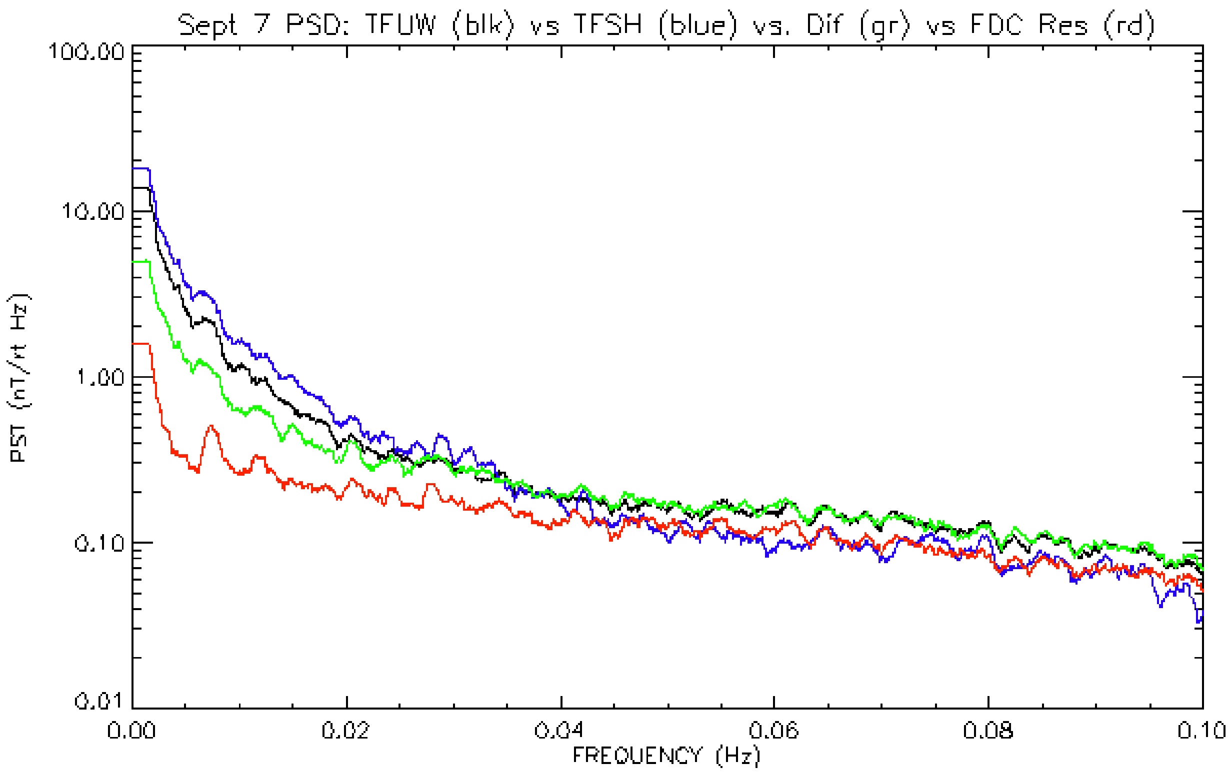
This is similar to the coherence seen in previous data sets where the undersea sensor was in very shallow water instead of the 259 m of water for these data.

Two methods were used to remove the geomagnetic noise – straight subtraction of the on-shore data and a frequency-domain cancellation method. Both were applied to the filtered data. The following plots show the residuals from the two methods and the PSDs of the various signals.



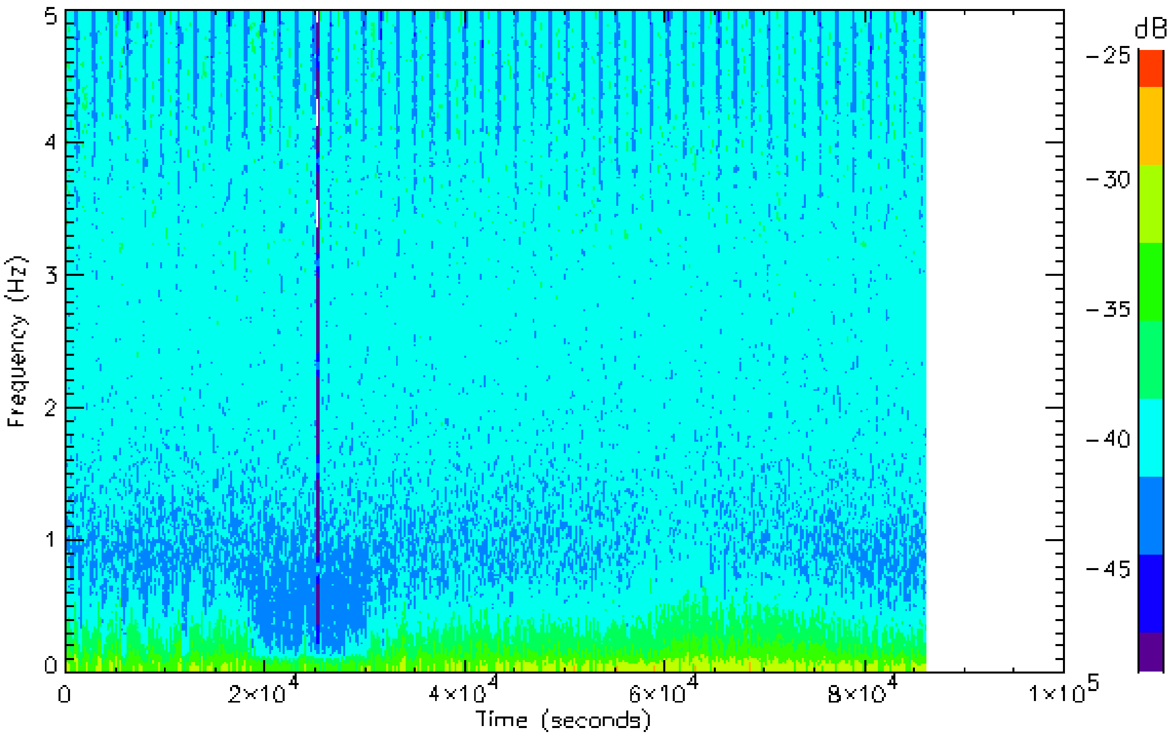
Here is a plot that just compares the difference and FDC residual.





Conclusion: The FDC method removes more noise than the simple difference. This is to be expected because the sensor is in 259 m of water so there is a skin-depth attenuation of the geomagnetic signals. This is consistent with what was found in Feb 2015 when undersea and on-shore data collected in Nov 2014 were analysed.

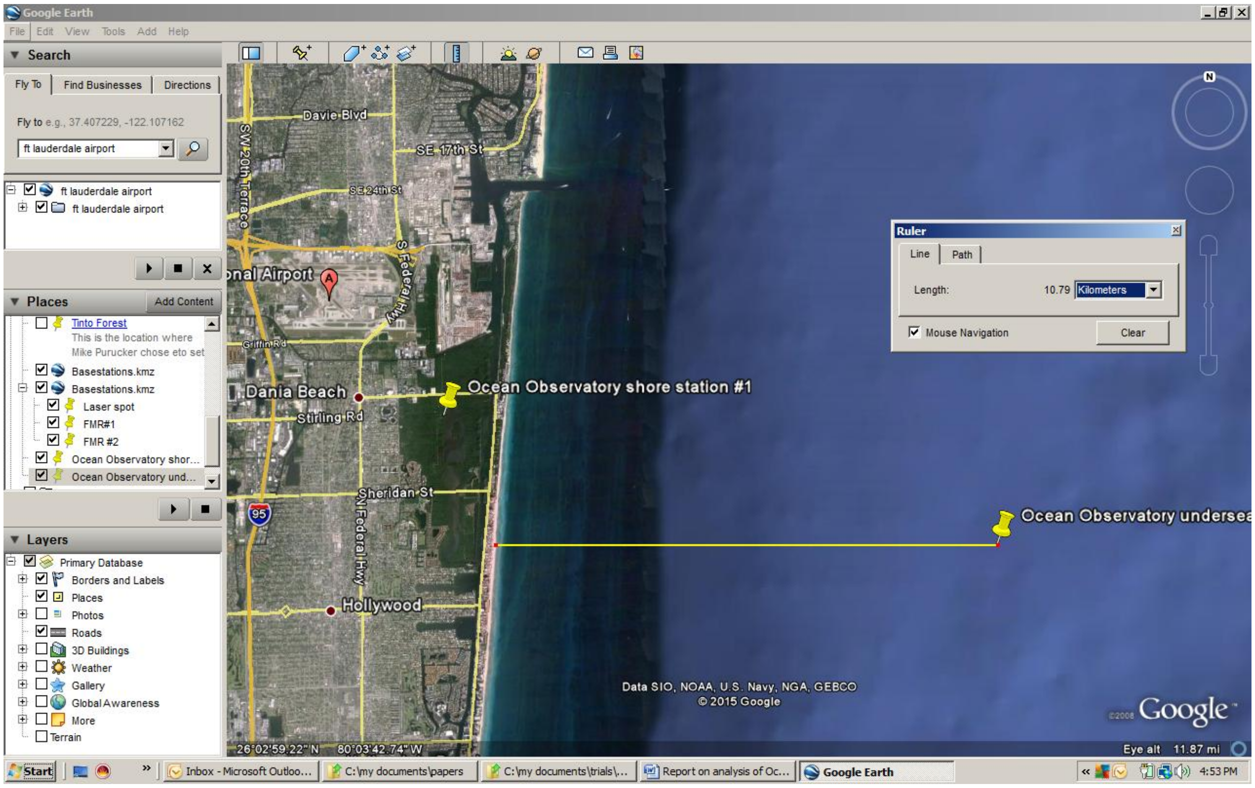
A spectrogram of the corrected (glitch-removed) undersea data was generated using 60-second long FFTs. The following figure shows the result:



There is a strong periodicity to the noise (~ 20,000 seconds/12 oscillations ~ 1666 seconds ~ 28 minutes) which is not understood, but it cannot be due to oceanographic sources.

The following plot shows the locations of the Ocean Observatory shore station and undersea sensors. The undersea sensors are ~ 11.4 km offshore, near 26° 1' 25.87"N; 80° 0' 23.92"W.

The shore station is roughly 2 km from the end of the Ft. Lauderdale airport south runway which just opened for operations in 2015.

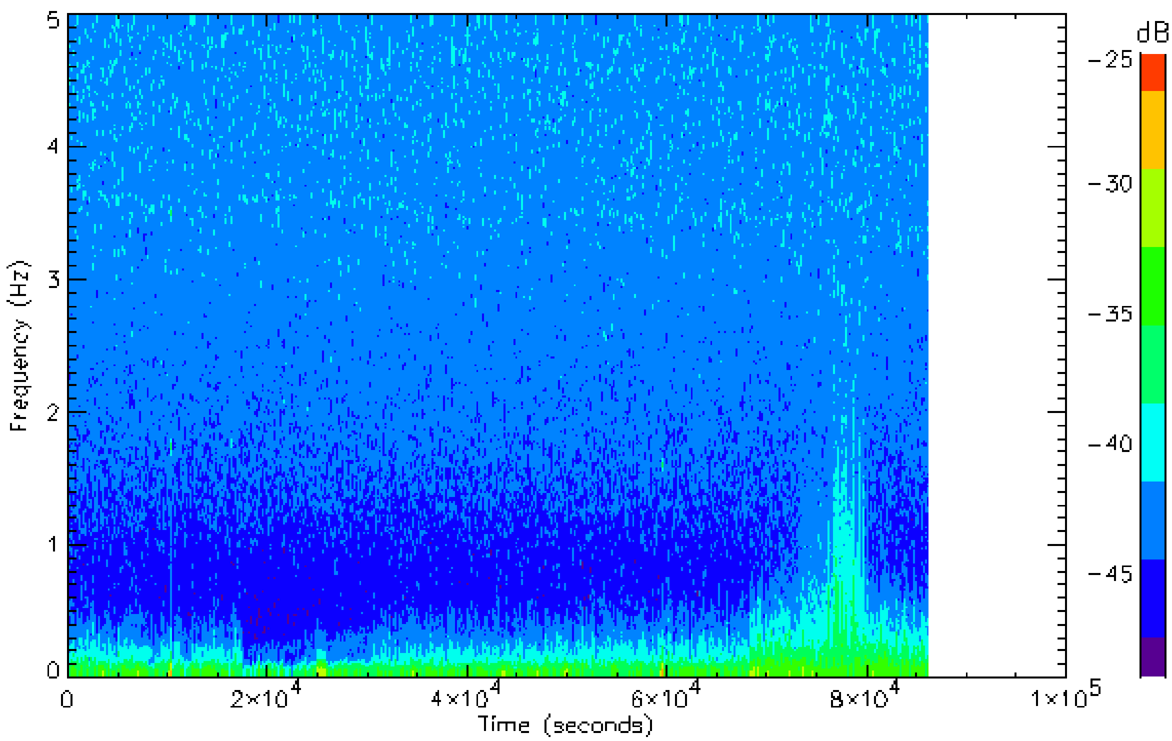


Location of shore station and undersea sensors for the Ocean Observatory project.

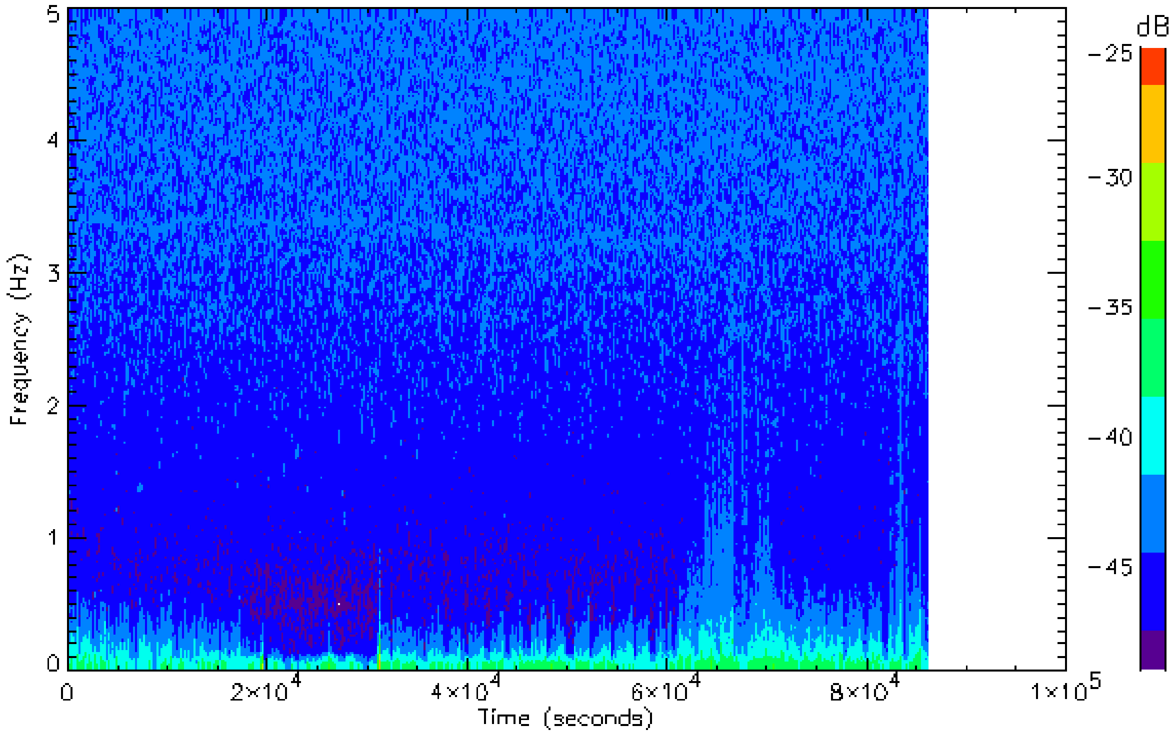
Appendix E: Comparison of undersea spectrograms for Sept 4, 5, 6, and 7, 2015

There appears to be a “quiet period” for each day, starting near 20000 seconds UTC and ending near 32000 seconds UTC. During this period there are no “odd” artifacts in the undersea TF data. The spectrograms for the 4 days are shown below. The final plot is the time series for Sept 7 from time = 15000-35000 seconds.

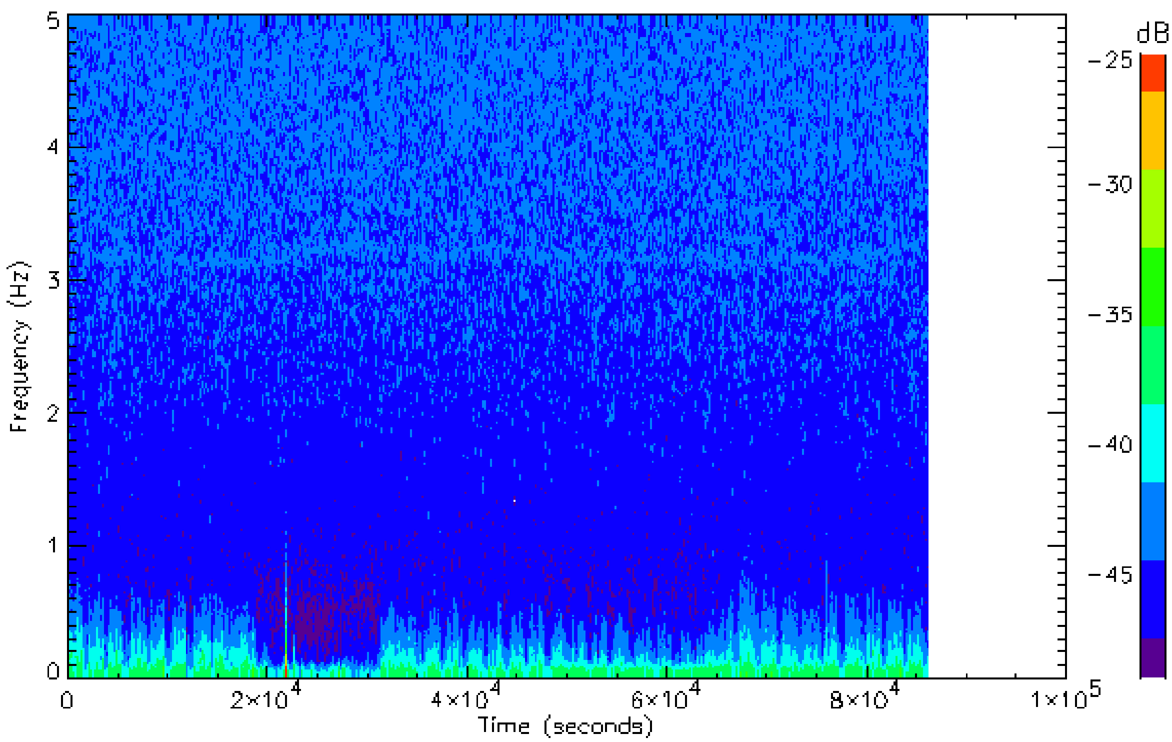
<u>1. What is the cause of this “quiet period”?</u>



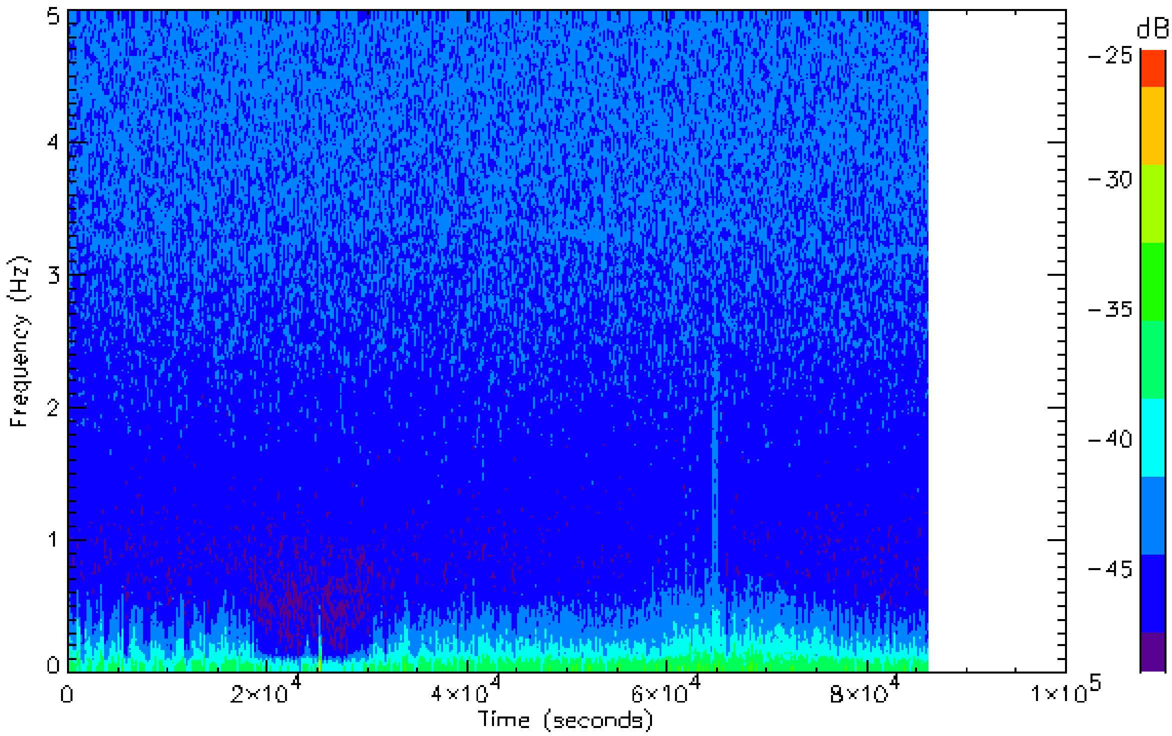
Sept 4, 2015 data without any glitch correction applied.



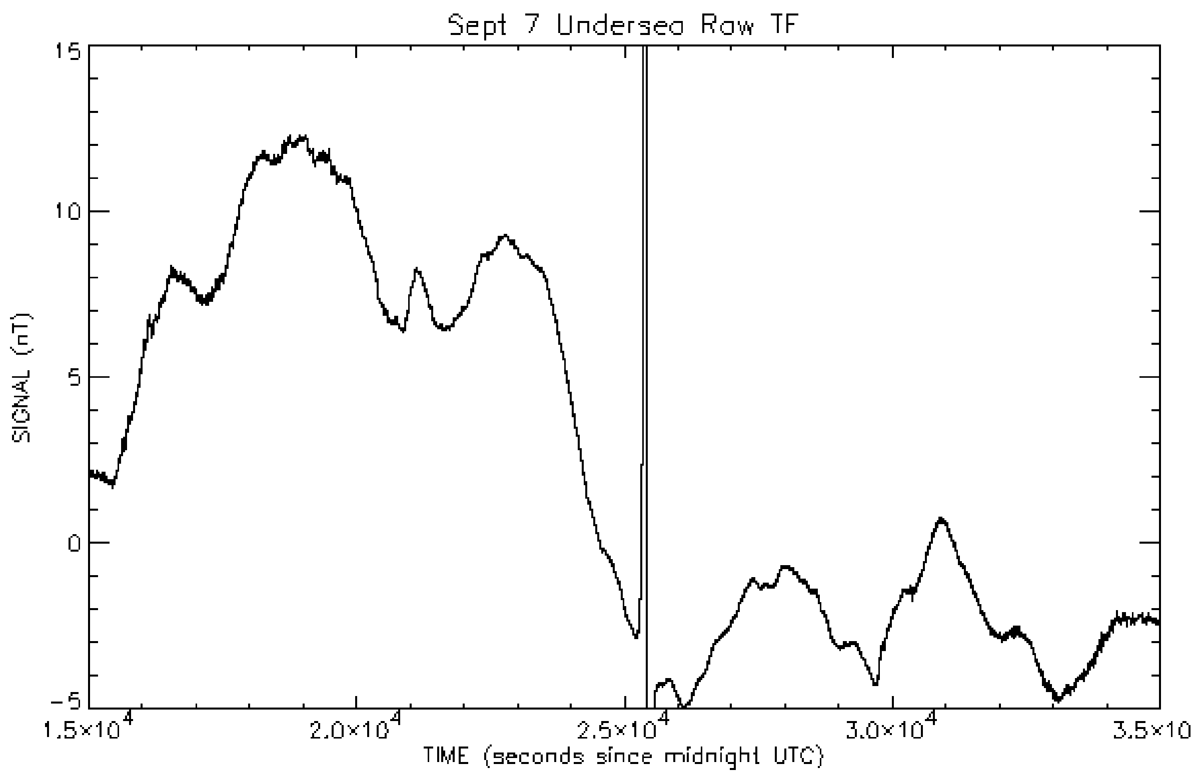
Sept 5, 2015 data without any glitch correction applied.



Sept 6, 2015 data without any glitch correction applied.



Sept 7, 2015 data without any glitch correction applied.



"Quiet period" starting near 20000 seconds and ending near 32000 seconds in Sept 7 data. (Large anomaly near 25500 seconds is a ship signature.)

Appendix F: Comparison of _31, _32, _34 and Jan 5 2015 movspdsr output

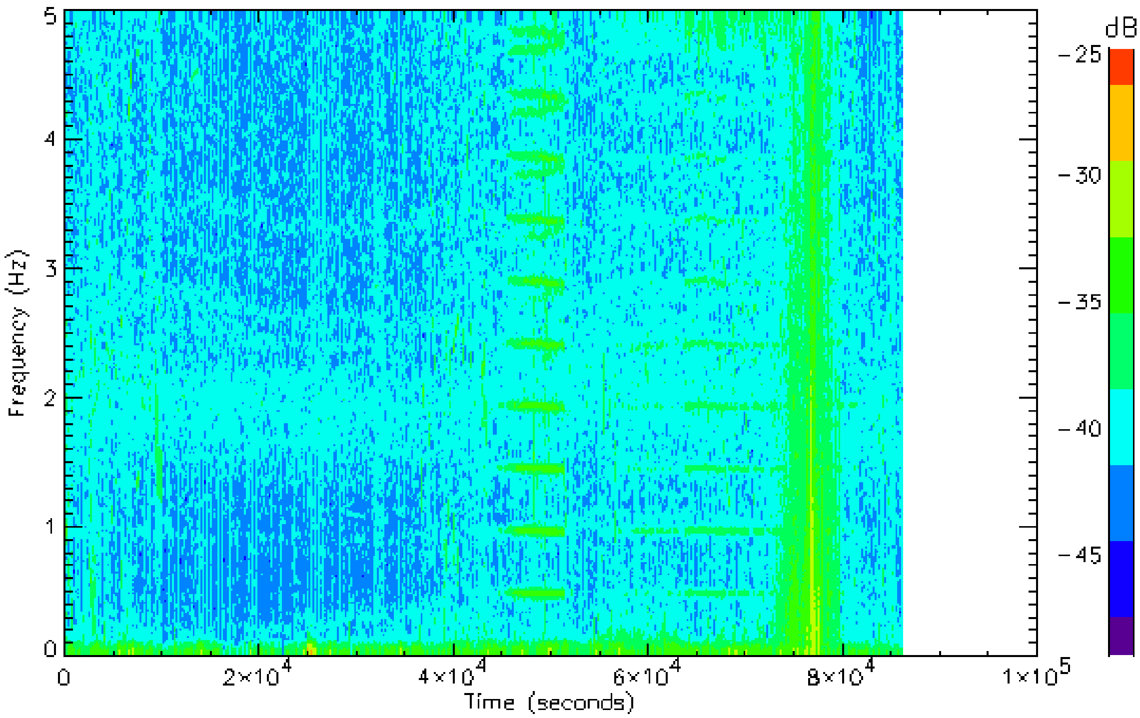


Figure 1. Spectrogram from 'TOA5_56936_MagData_31.dat'

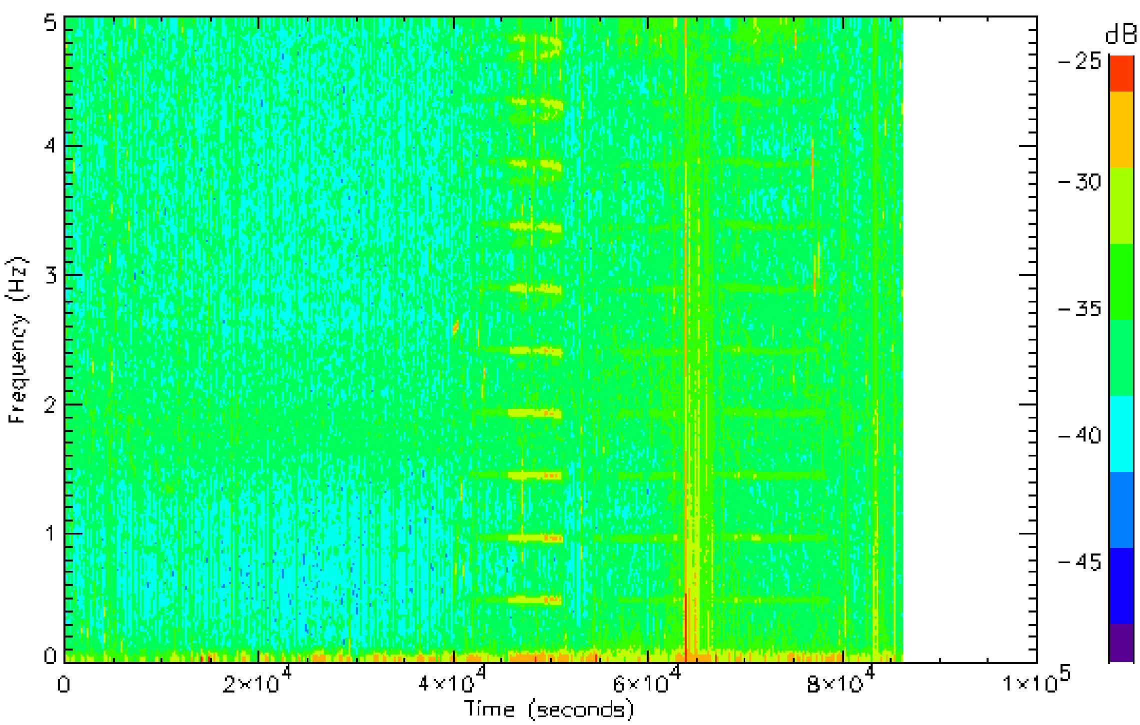


Figure 2. Spectrogram from 'TOA5_56936_MagData_32.dat'

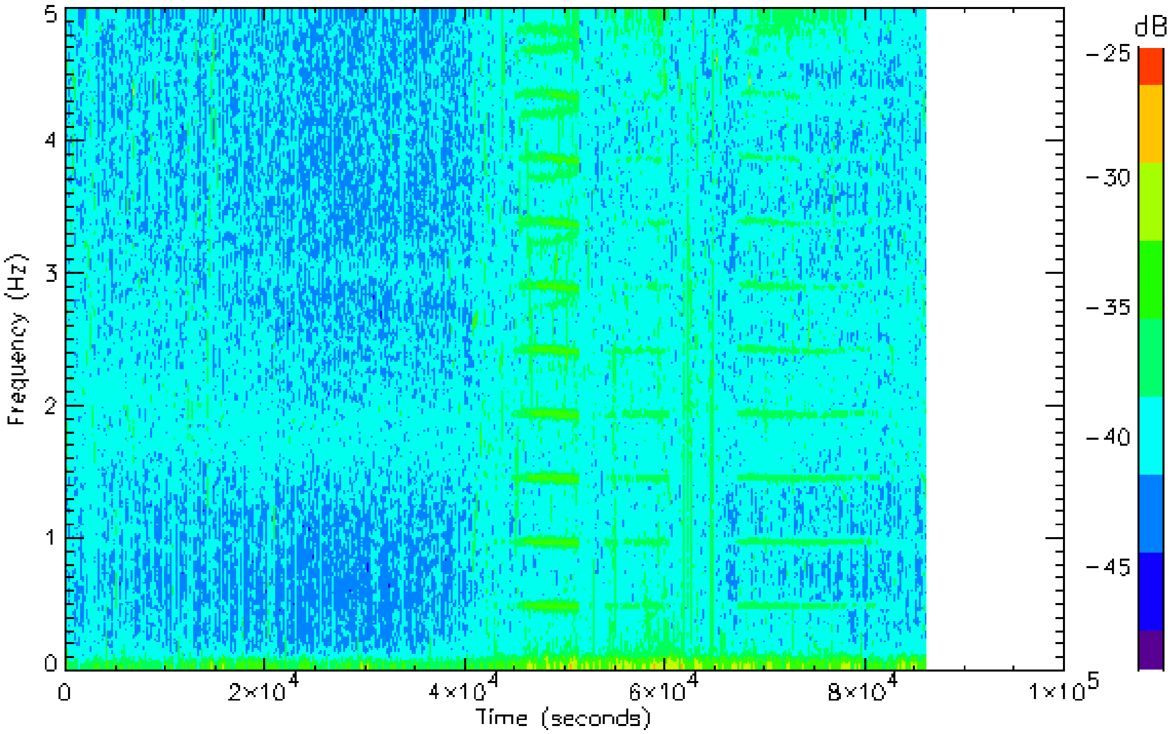


Figure 3. Spectrogram from 'TOA5_56936_MagData_34.dat'

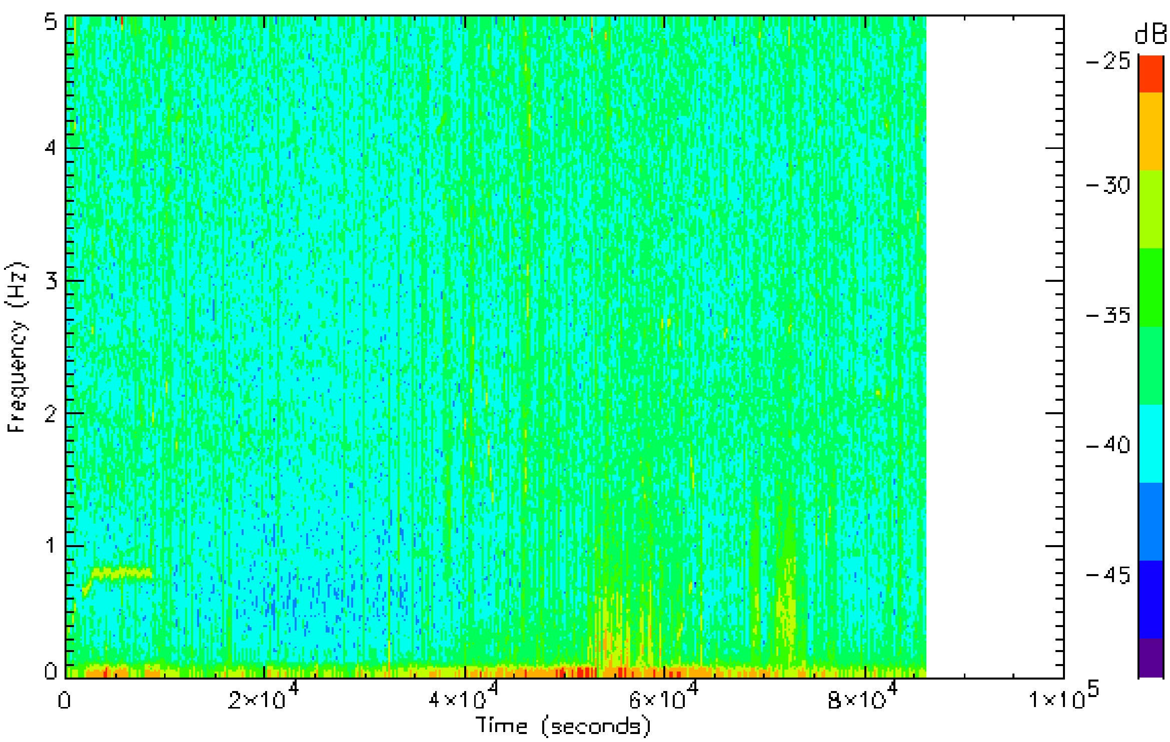


Figure 4. Spectrogram from ' TOA5_56936_MagData_100_2015_01_05_0000.proc'

There appears to be a harmonic source that comes on around 45000 seconds ~ 12:30:00 UTC each day of the _31, _32, and _34 data sets. However, there is no hint of the same harmonic source in the Jan 2015 data. The conclusion must be that something has changed near the park since Jan 5, 2015 that is creating that harmonic source.

Appendix G: Comparison of Aug 2015 charging configurations in shore station magnetic data

dr='C:\my documents\trials\SFOMF data for NICOP 1\Sept9-2015\shore station\8-28-15 collection(ON-OFF Charging)\converted\'
fil='TOA5_56936_MagData_22.dat'
ReadBaseStationMag,timON_OFF,mag1ON_OFF
movpsdsr,10,60,mag1ON_OFF,outON_OFF,y,x

The harmonic structure begins around 44000 seconds UTC ~ 9:00 am local time ~ 12:00 UTC.

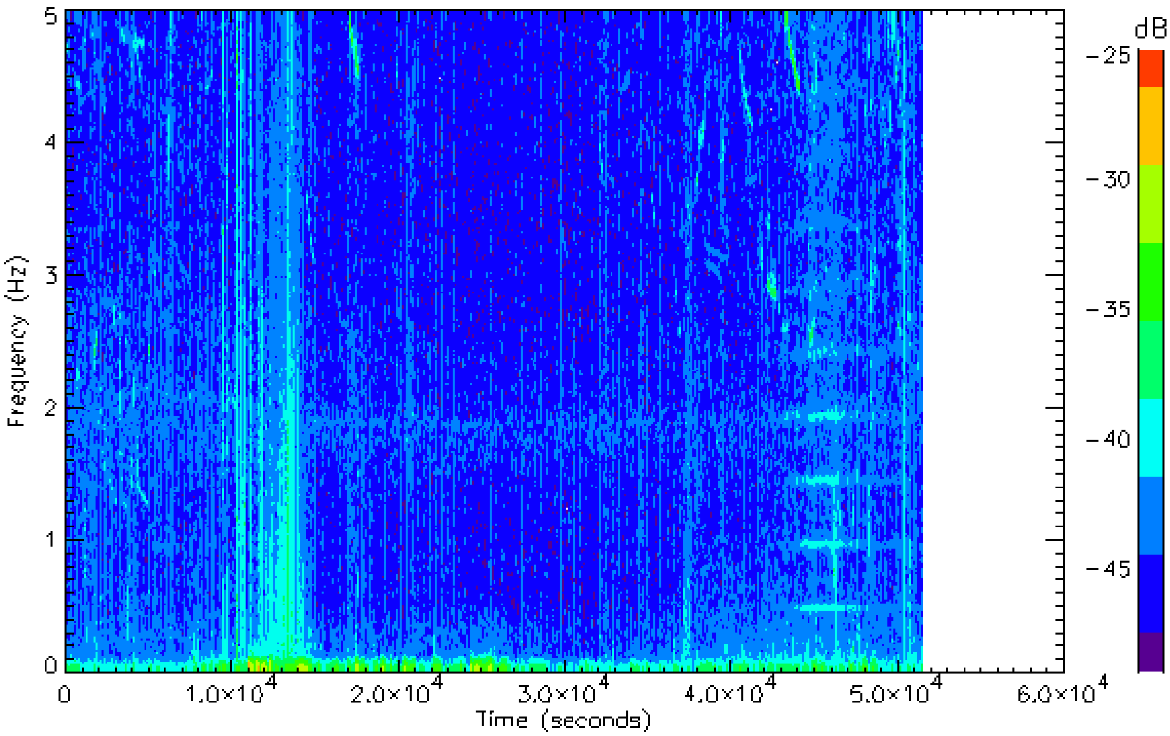


Figure 1. Spectrogram of data with ON-OFF charging.

Now compare it to the Pulse Width Modulation (PWM) charging for Aug 26.

dr='C:\my documents\trials\SFOMF data for NICOP 1\Sept9-2015\shore station\8-26-15asci\'
fil='TOA5_56936_MagData_5.dat'
ReadBaseStationMag,timPWM,mag1PWM
movpsdsr,10,60,mag1PWM,outPWM,y,x

The harmonic structure also begins around 44000 seconds UTC ~ 9:00 am local time ~ 12:00 UTC. We checked several other days and it is definitely the same periodic feature in the spectrogram, always starting near the same time.

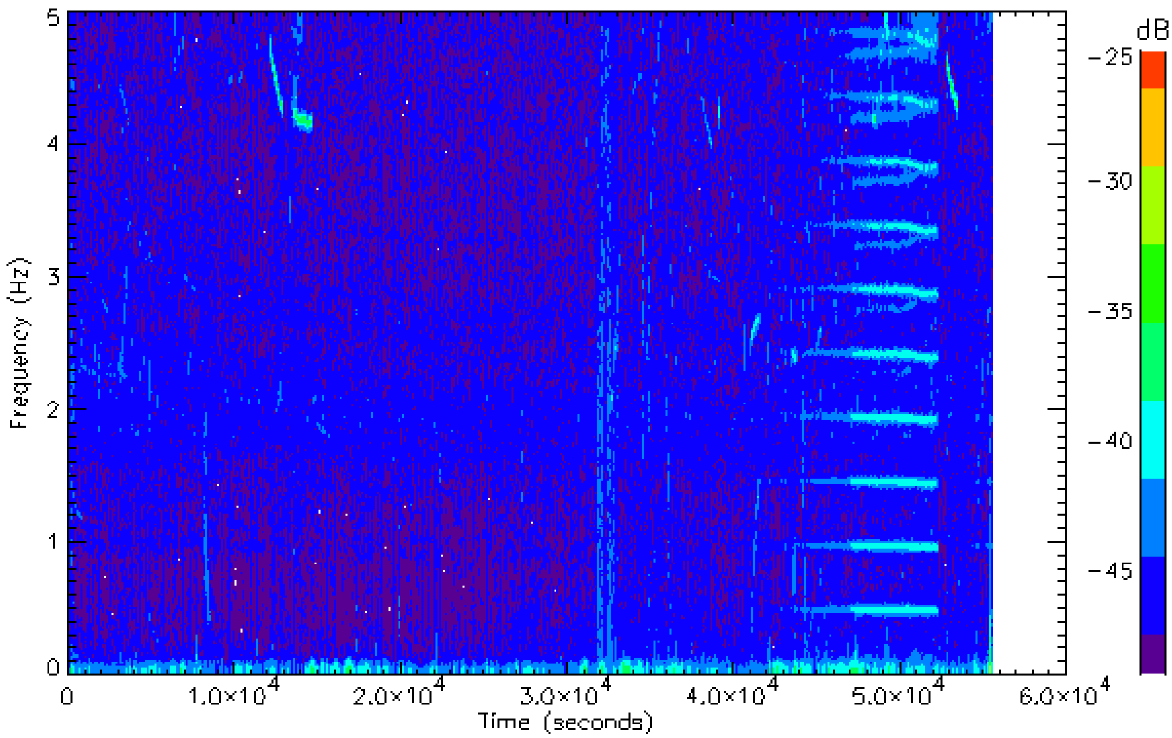


Figure 2. Spectrogram of data with Pulse-Width Modulation charging.

The following information was taken from the Feb 2015 version of the on-shore manual, with additional information supplied by George Valdez during phone calls on Oct 16.

<u>SPS Component Cables</u>

- 2 MC4 cables
- 14AWG

<u>SPS Component Hardware</u>

- 10A ATC fuse
- ATC fuse block
- IronRidge solar panel mount (IronRidge)
- Grounding spike
- 2 grounding lugs
- Marine Box (Box)

<u>SPS Components</u>

- Two Trojan 12V Deep Cycle Gel batteries (Trojans)
    - (14X7X11 each)
- ET Module 250 Watt Solar Panel (ET)
- Morningstar ProStar-15 PWM Charge Controller (ProStar)
- 24V to 12V voltage regulator (Converter) NOT used anymore!

On August 14 2015 the system was changed to an 1800 Watt solar converter. Two switching boost converters 18-75 Volt to maintain 28 Volts to the magnetometer. There is a second system to maintain 12 Volts to the other electronics.

Discussions with George Valdez says the charging system changed on August 14. He says may not have any data from late Feb-Aug because the magnetometer went back to Geometrics for repair. There were significant problems (as identified by my analysis in Feb 2015) that Geometrics solved by replacing bad components in the physics package.

We asked George to collect a few days of data without the charging system running in order to determine if the harmonic noise is actually caused by the charging system, or if it is really due to a changing magnetic environment at the shore station.

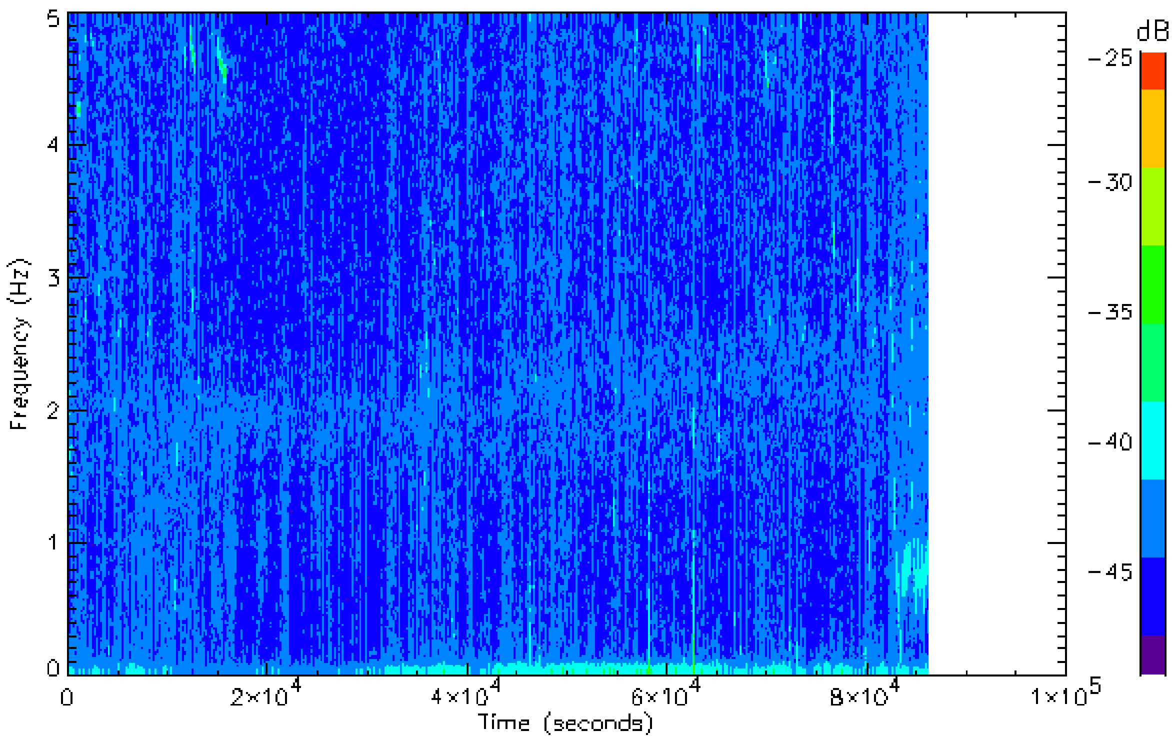
Appendix H: Quick analysis of SFOMF data with solar charger by-passed

In IDL, do the following to generate the plots:
filein='C:\my documents\trials\SFOMF data for NICOP 1\shorestation-chargesystembypassed Oct 26\TOA5_56936_MagData_89.dat'

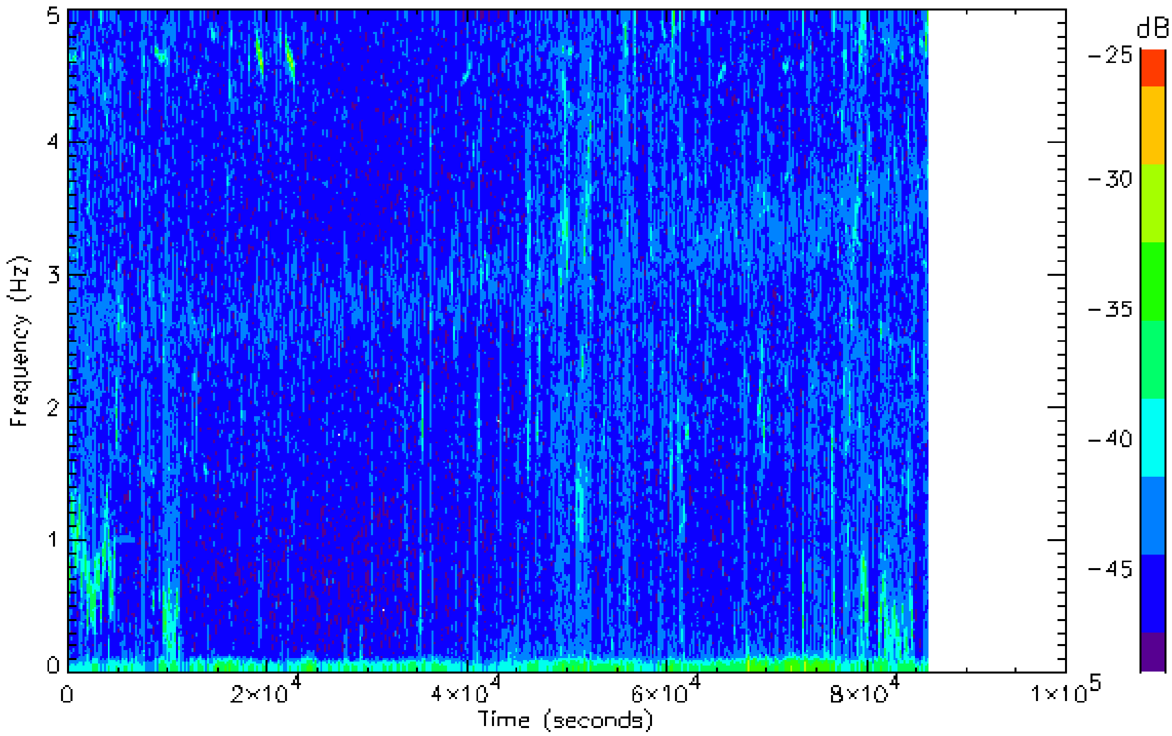
simply change the filein to ……….._90.dat   or _91.dat to look at other days

ReadBaseStationMag,filein,tim,mag1
plot,mag1,/ynoz &wshow
movpsdsr,10,60,mag1,out,y,x &wshow

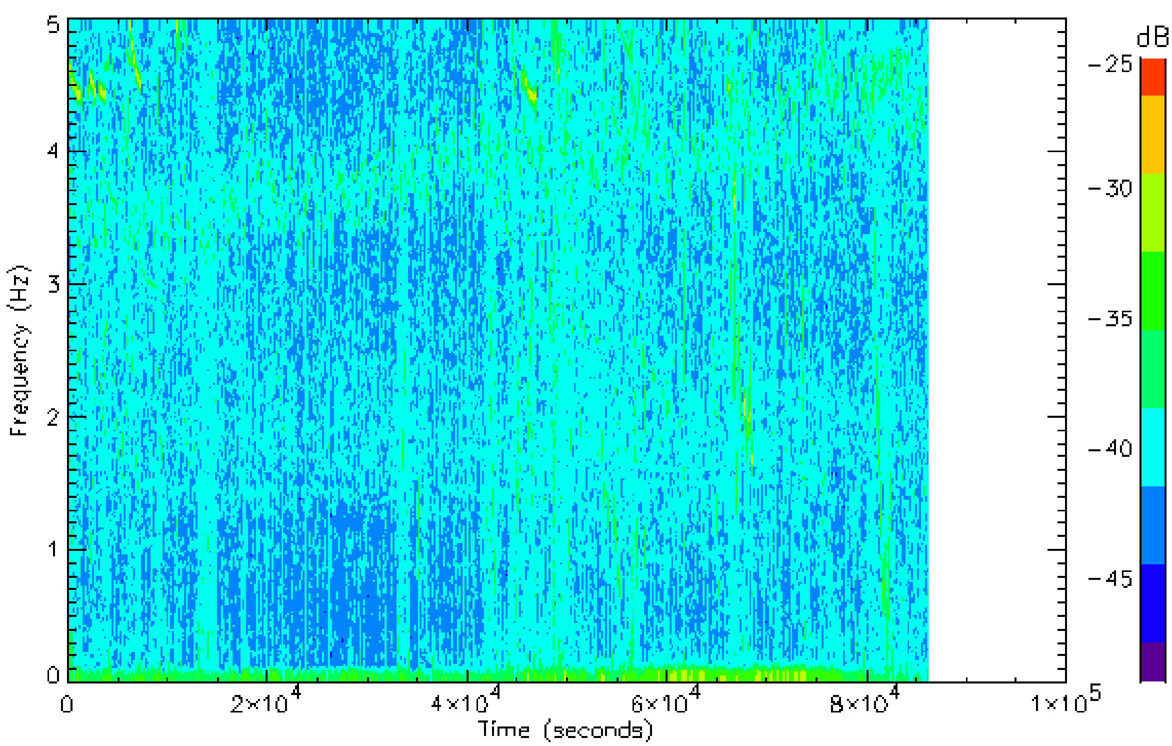
For Day 89, the Spectrogram looks like this:



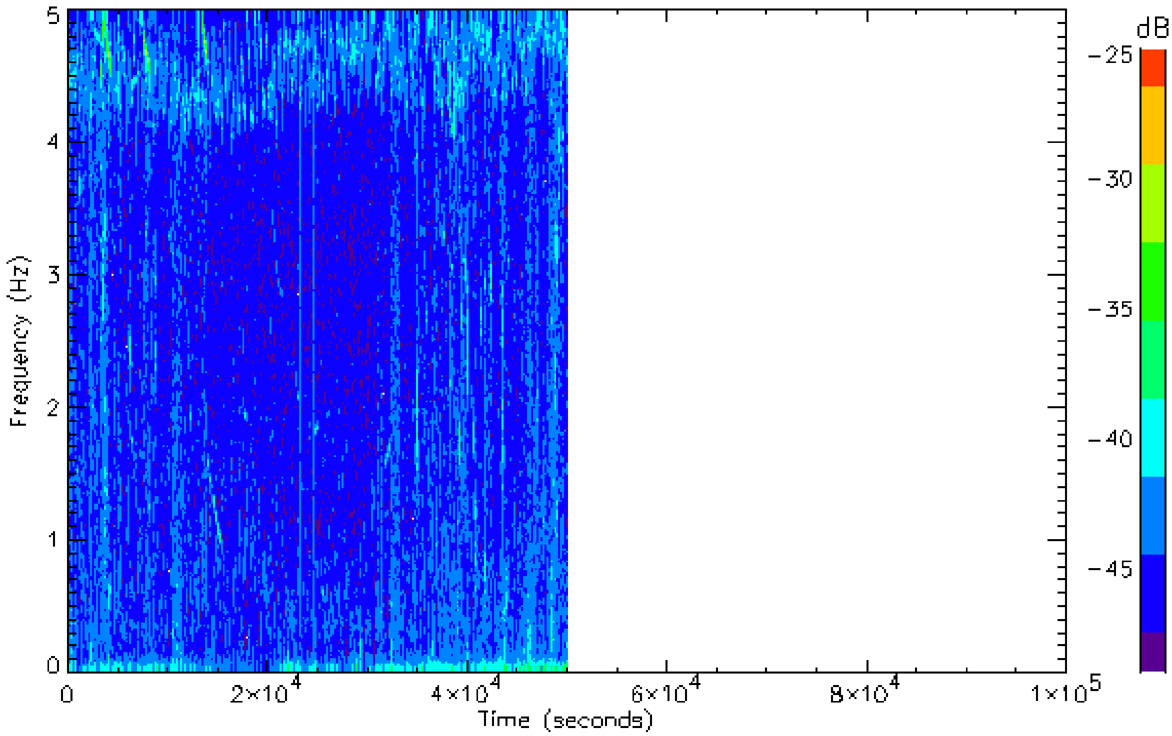
For day 90 the spectrogram looks like this:



For Day 91, the spectrogram looks like this:



Day 92 looks like this



<u>Conclusion:</u> There is no hint of the periodic noise seen on all other days since the solar power charger system was installed. Thus I believe the periodic noise is caused by the solar charger system.

The data collection lasted from

2015-10-22 14:21:56.9
2015-10-26 13:56:57.41

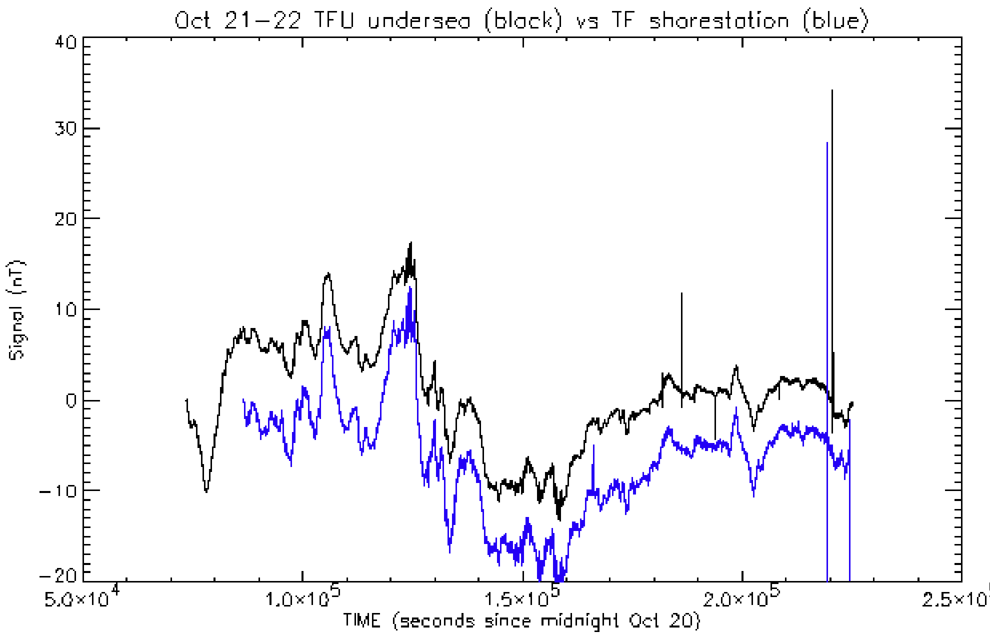
~ 4 days 23 hours 36 minutes ~ almost 4 days

Appendix I: Analysis of Oct 21-22 2015 offshore vs. on-shore magnetic data

Off-shore data file:	20151022 MagLogAppend.txt
On-shore data files:	TOA5_56936_MagData_86.dat
	TOA5_56936_MagData_87.dat

IDL routine: compare_Oct_20_22_shore_and_offshore.pro

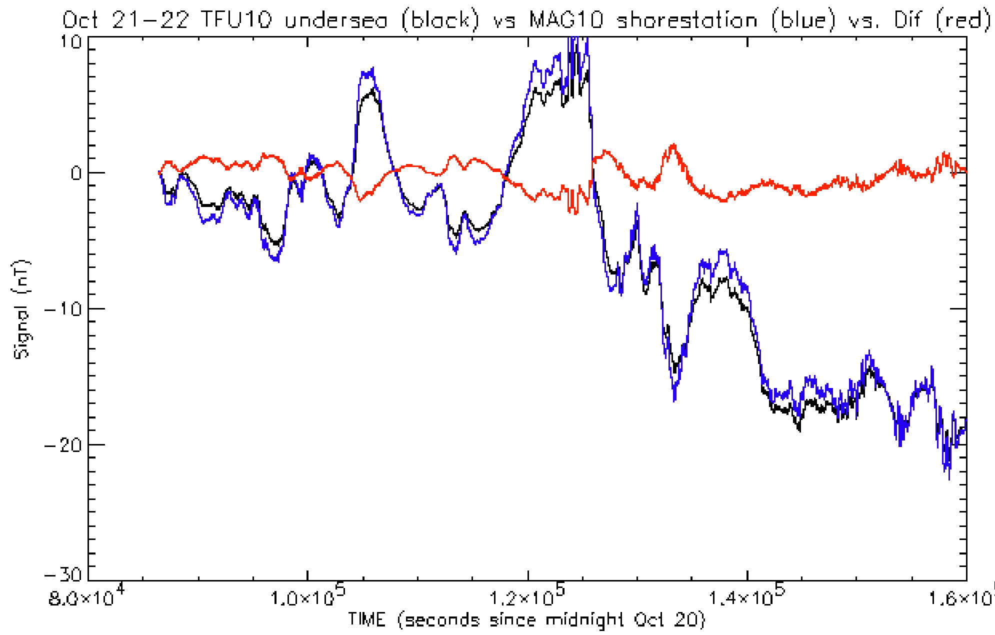
First compare the raw time vs TF for both the undersea and onshore data.



Although there appears to be a high degree of correlation, careful analysis showed that the undersea time was 1 second ahead of the onshore data. Thus in the IDL code, 1 second was subtracted from the undersea time.

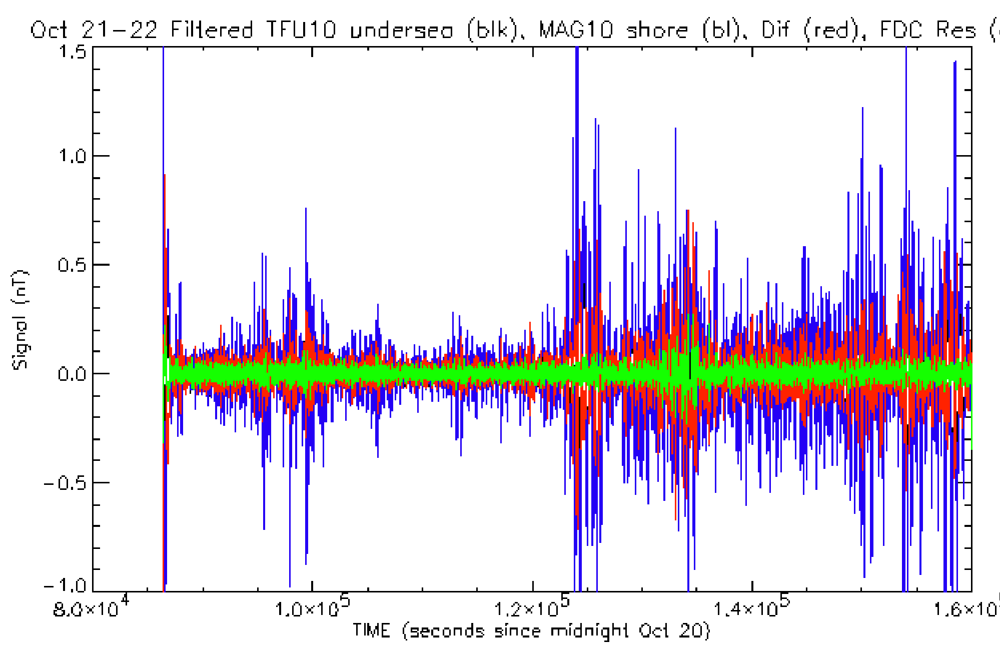
To avoid the ship signatures in the undersea data and the large spikes in the onshore data, the analysis was only conducted over time = 86400.1 – 160000.0 seconds.

I re-sampled each to exactly 10 Hz over the time range 86400.1 – 160000.0 seconds using an Akima Spline fit. There were 9 NaN values in a row in the output from the TFU10 so these were set to the last good value before the NaN values. The following plot shows the undersea total field (TFU10), the onshore total field (MAG10), and the difference (TFU10-MAG10) all plotted vs. the re-sampled time (TIME10).

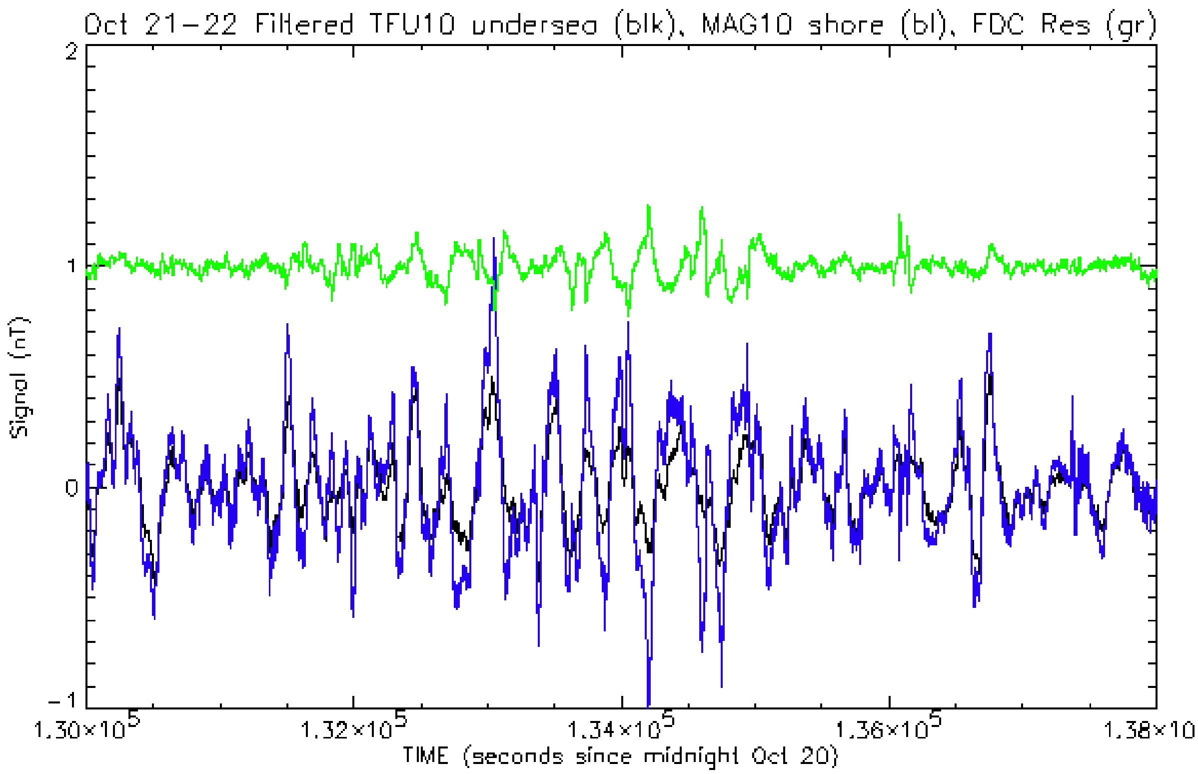


It is clear from the above plot that a simple subtraction of the onshore TF is NOT a sufficient method for geomagnetic noise removal for the situation where the undersea sensors are in deep water. The skin-depth effect reduces the amplitude of the geomagnetic variations at the seafloor. This is consistent with previous analyses.

A frequency-domain cancellation (FDC) method was applied in order to remove the geomagnetic variations. This algorithm assumes a zero-mean time series so both the TFU10 and MAG10 data were filtered with a 0.002-0.5 Hz 4^{th}-order Bessel filter, yielding the quantities TFU10bp and MAG10bp. The following plot shows TF10bp, MAG10bp, the simple difference (TF10bp-MAG10bp), and the FDC Residual.

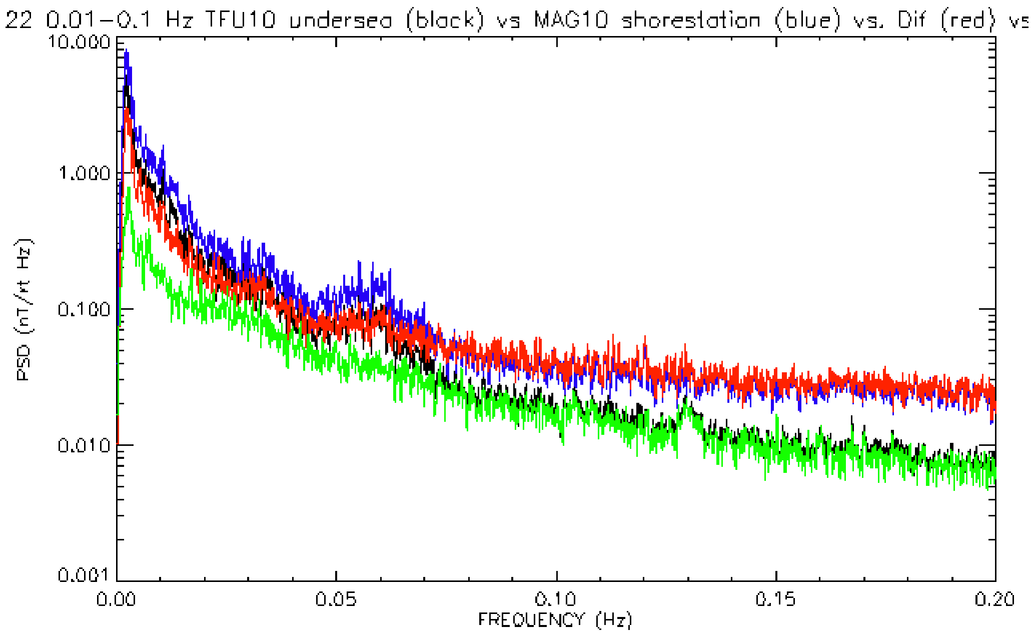


The next plot shows the PSDs of the same 4 quantities. The green trace indicates that there may be some oceanographic signals in near 132000-135000 seconds. Here is a zoomed in plot showing just that time period.

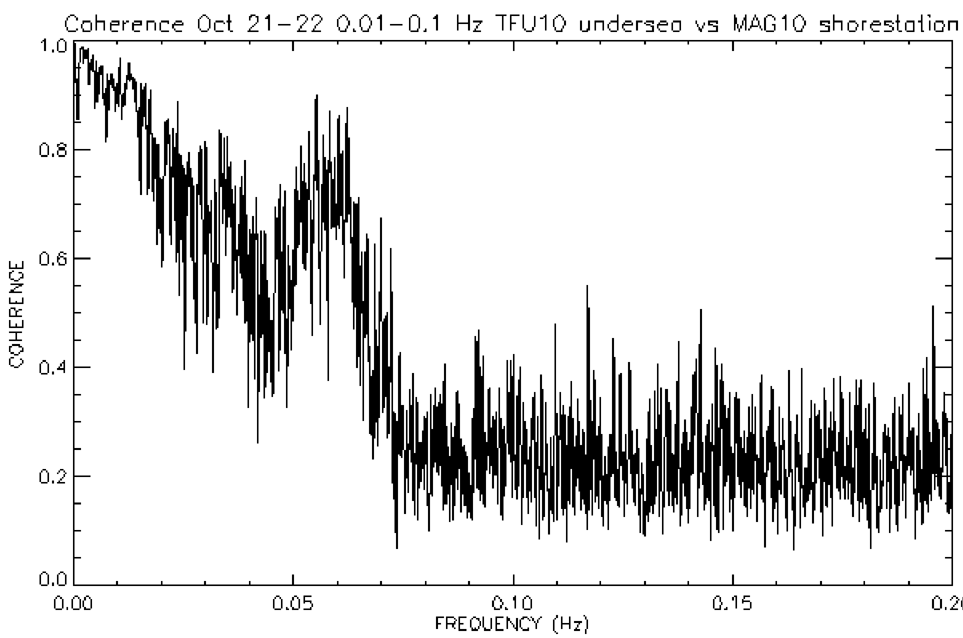


This shows that the undersea and onshore signals are still highly coherent. The FNC Residual signal (green) does not appear to be due to undersea signals (black) that are not occurring in the onshore magnetometer (blue), instead it appears they are due to an incorrect transfer function. Thus I do not believe that the FNC Residual signals near 132000-135000 seconds are indicative of oceanographic sources.

Here is a plot showing the power spectral densities (PSDs) of the entire TF10bp, MAG10bp, Dif, and FDC Residual time series.



Finally, the next plot shows the coherence between the TFU10bp and MAG10bp signals.



Conclusions:

1) there was a 1 second difference between the undersea and onshore timestamps. To correct this, 1 second was subtracted from the undersea timestamp.

2) Although there was a clear correlation between the undersea and onshore magnetic data, the skin-depth effect reduced the amplitude of the geomagnetic variations at the undersea magnetometer. This

resulted in very poor geomagnetic noise reduction if only a simple subtraction of the onshore magnetic signal (MAG10) was used.

3) A frequency-domain cancellation method was used which accounts for this skin-depth effect. The geomagnetic noise cancellation was significantly better using this technique than with simple subtraction.

4) At first glance there appeared to be evidence of oceanographic signals around 132000-135000 seconds. However, closer examination show that the signals appear in both the undersea and onshore magnetometer data, suggesting an incorrect transfer function instead of oceanographic signals.

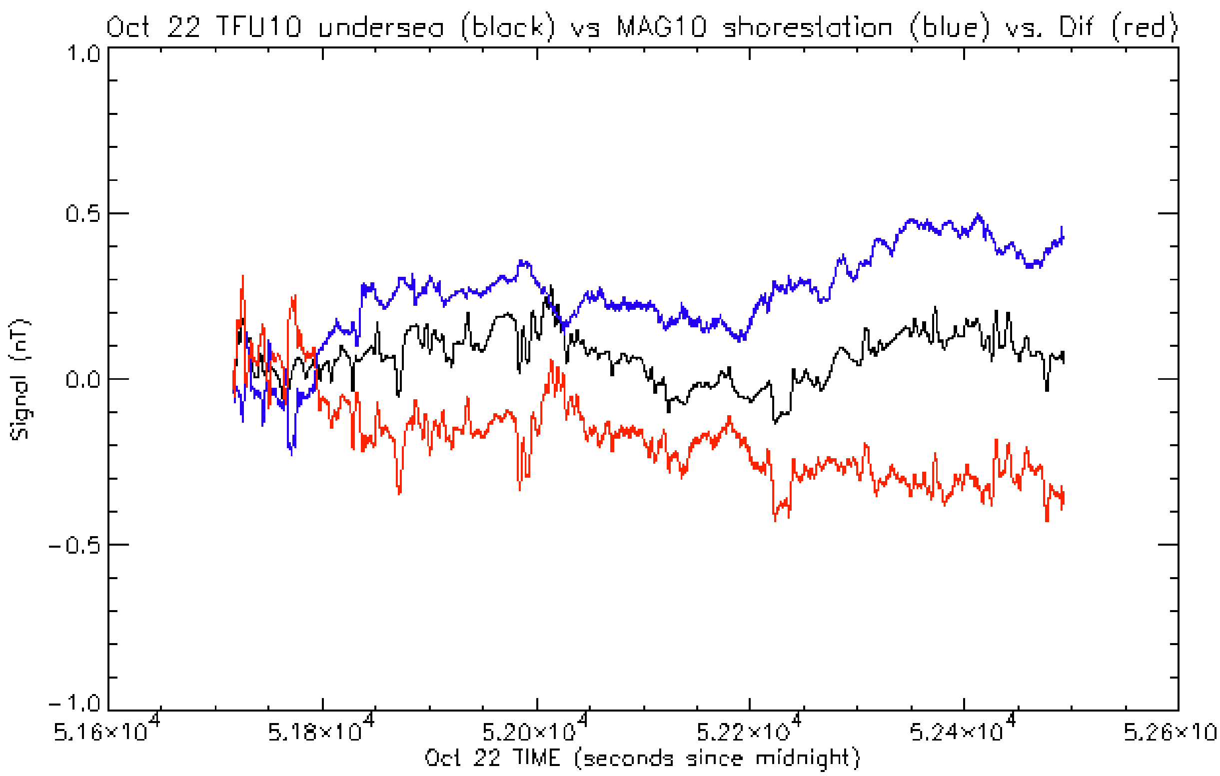
5) The coherence between the undersea and onshore magnetometer signals is > 0.9 for frequencies < 0.02 Hz. However, there is a secondary bump in the coherence around 0.06 Hz where there was a significant amount of geomagnetic activity (P3c pulsations?). This activity can be seen in the time series of the first plot and in the PSD plots.

Appendix J: Comparison of Oct 22 offshore and on-shore TF data

Method: Read the off-shore and on-shore data into IDL, re-sample @ 10 Hz to the start and end times where the files overlap. Plot up the re-sampled off-shore (black), on-shore (blue), and difference (red), all with the DC value of the first DP subtracted off. A 21 DP boxcar smoother (2.1 seconds) has been applied to remove the high-frequency noise, especially from the on-shore magnetometer.

Conclusion: There are certainly features seen in the undersea TF that are not apparent in the onshore TF data. The question though is whether or not it is oceanographic in origin.

Note I did NOT shift either time series for these plots. At first I thought I should shift the blue trace by about 20 seconds to make the low-frequency peak near 52000 seconds match up, but it's not really clear that that is the correct thing to do, so I left it as is. Also, a proper analysis would take account of the skin depth effect on the undersea TF (that is, the shorestation TF would be low-pass filtered to match the effect of passing through the appropriate depth of water, then subtracted from the undersea TF to yield a slightly different Dif (red) trace.



Here is the analysis routine

```
pro compare_Oct_20_22_shore_and_offshore
;
```

```
; this procedure reads in the SFOMF on-shore and offshore data to see if there are any 10-20 second
artifacts in the off-shore data
;
initial
;
; read in the offshore data
;
dford,8,nr,a,'C:\my documents\trials\SFOMF data for NICOP 1\ADCP vs current test\20151022
MagLogAppend.txt'
colext,a,day,2
window,2
plot,day
;
; find data for Oct 22
;
q=where(day eq 22) &print,q(0)
a=a(*,q(0):*)
timeU=tovect(a(3,*)*3600.d0+a(4,*)*60.d0+a(5,*)+a(6,*)/1000.d0)
colext,a,TFU,7
colext,a,day,2
;
; we now have the timeU, TFU, and day for just Oct 22
;
window,0
plot,timeU,TFU,color=0,background=-1,xtitle='Oct 22 TIME (seconds since midnight)',ytitle='Signal
(nT)',title='Oct 22 TF undersea',/ynoz &wshow
;
; read in the shorestation data for Oct 22, 2015
;
filein='C:\my documents\trials\SFOMF data for NICOP 1\shorestation-chargesystembypassed Oct
26\TOA5_56936_MagData_88.dat'
ReadBaseStationMag,filein,tim,mag1
;
; overplot the shorestation TF
;
window,1
plot,timeU,TFU-TFU(0),color=0,background=-1,xtitle='Oct 22 TIME (seconds since
midnight)',ytitle='Signal (nT)',title='Oct 22 TFU undersea (black) vs TF shorestation (blue)'
oplot,tim,mag1-mag1(0)
;
time0=tim(0)
timeend=max(timeU)
ndp=(timeend-time0)*10L+1L
time10=dindgen(ndp)*0.1+time0
;
spakim,timeU,TFU,time10,TFU10
spakim,tim,mag1,time10,mag10
dif=TFU10-mag10
```

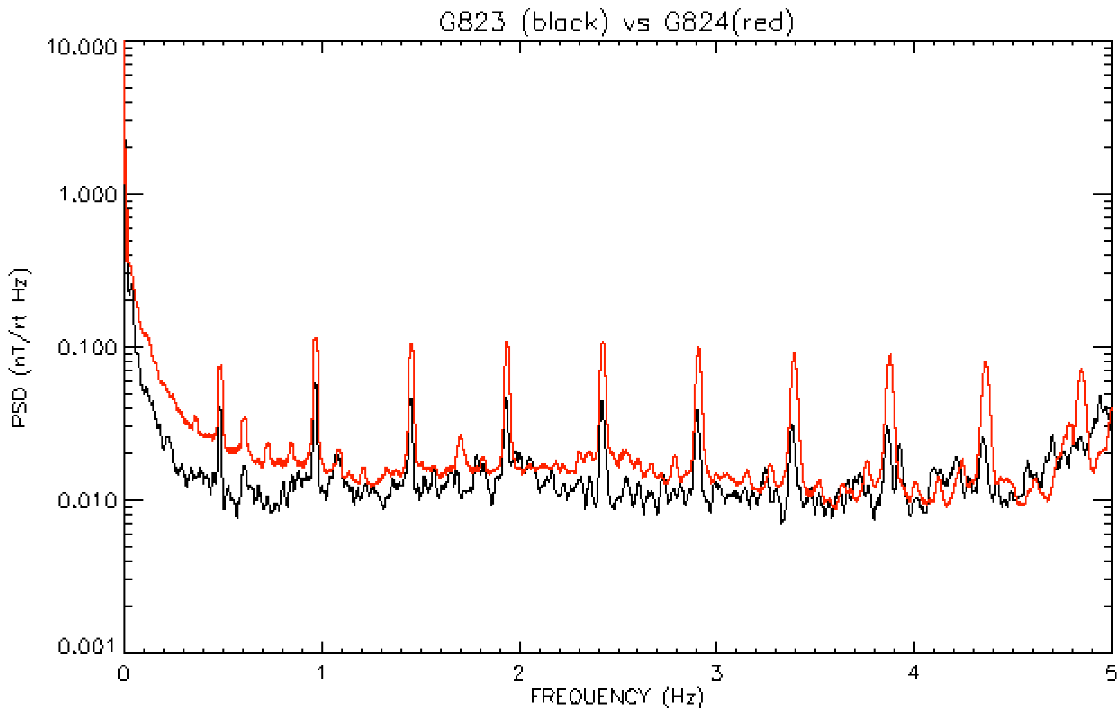
```
;
window,2
plot,time10,smooth(TFU10-TFU10(0),21),yrange=[-1,1],color=0,background=-1,xtitle='Oct 22 TIME
(seconds since midnight)',ytitle='Signal (nT)',title='Oct 22 TFU10 undersea (black) vs MAG10 shorestation
(blue) vs. Dif (red)'
oplot,time10,smooth(mag10-mag10(0),21),color=50
oplot,time10,smooth(dif-dif(0),21),color=230

return
end
```

Appendix K: Comparison of G823 and G824 groundstation spectra

Purpose: To determine if the noise frequencies are the same in the G823 data (SR=10 Hz) and the G824 (SR=125 Hz).

Analysis: The following plot shows a comparison of the power spectra from the G823 and G824 data collected at the same time. The G823-charger station separation was approximately twice the G824-charger station separation. The sampling rate of the G823 was 10 Hz while that of the G824 was 125 Hz.

Conclusion: Both sensors see the same frequencies in the noise spectra so there are not a lot of aliased lines in the G823 spectrum. The amplitudes are different because the G824 was closer to the charger station.



Appendix L: Analysis of ADCP current vs ADCP+mag current vs TF measured

Fileid: 20151020_ADCP_Mag_Current_Fs-5k.csv (use HxD to replace : with space)
20151020_Mag_Only_Current_Fs-5k.csv (use HxD to replace : with space)
20151022 MagLogAppend.txt (use HxD to replace hex 0D with 20,
then replace hex 0A with 0D 0A,
then replace space $ space with space)

Method:

To read the current files into IDL

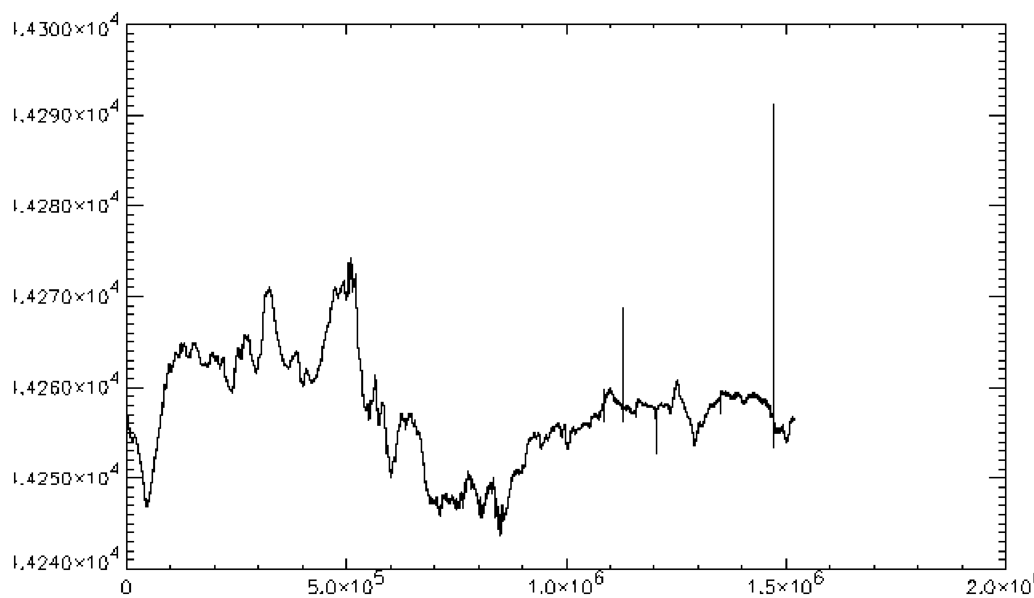
```
dford,5,nr,a,fileid
time=tovect(a(1,*)*3600.d0+a(2,*)*60.d0+a(3,*))
colext,a,I,4
```

To read mag file into IDL

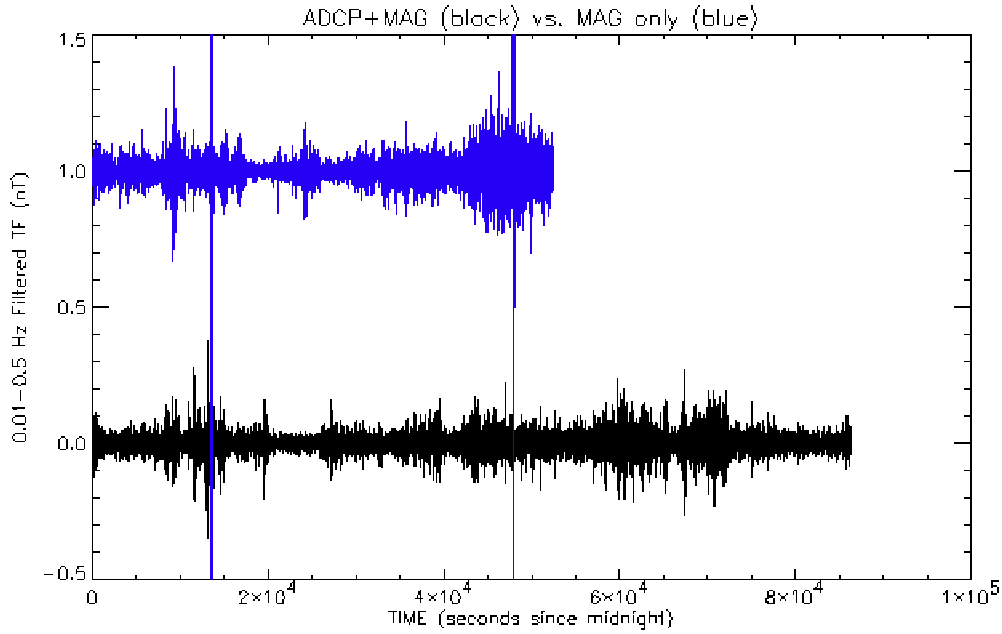
```
Dford,8,nr,mag,filemag
Timemag= tovect(mag(3,*)*3600.d0+mag(4,*)*60.d0+mag(5,*)+mag(6,*)/1000.d0)
Colext,mag,tf,7
```

Analysis:

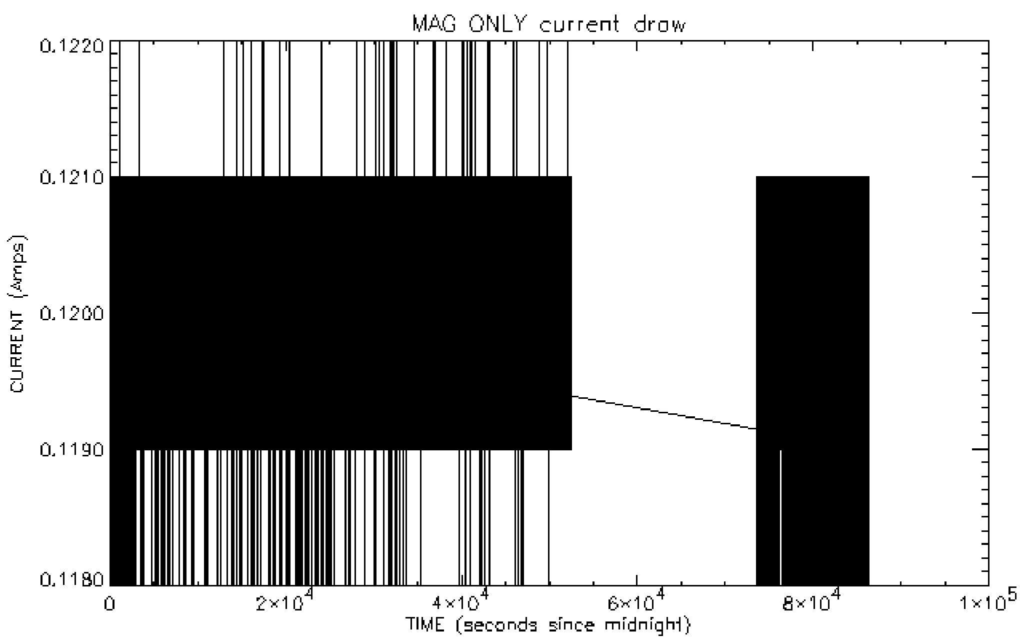
First look at the magnetic dat. Here is a time-series plot of all the underwater magnetometer data (skipped the first 1000 points when the magnetometer wasn't locked). There are several obvious ship signatures after DP 1,100,000)

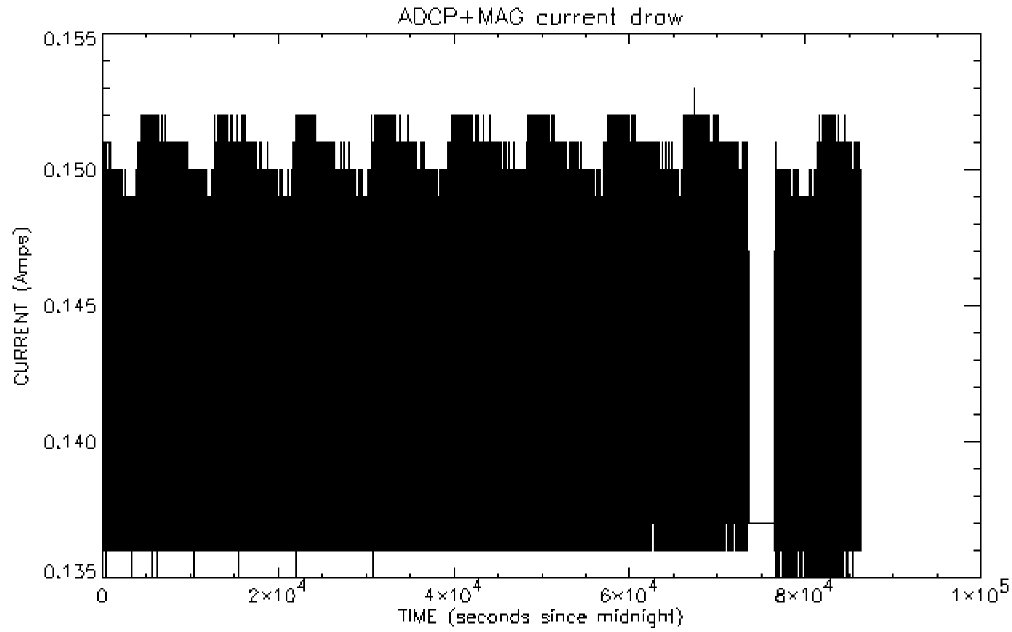


Next I filtered the total-field from 0.01 to 0.5 Hz (4th-order Bessel filters) and plotted the filtered TF vs time. The aim was to see if there was any obvious difference on the day when both the ADCP and MAG were turned on. This is shown in the following plot. There is no obvious difference – both show periods of relative quiet and periods of activity with similar amplitudes.



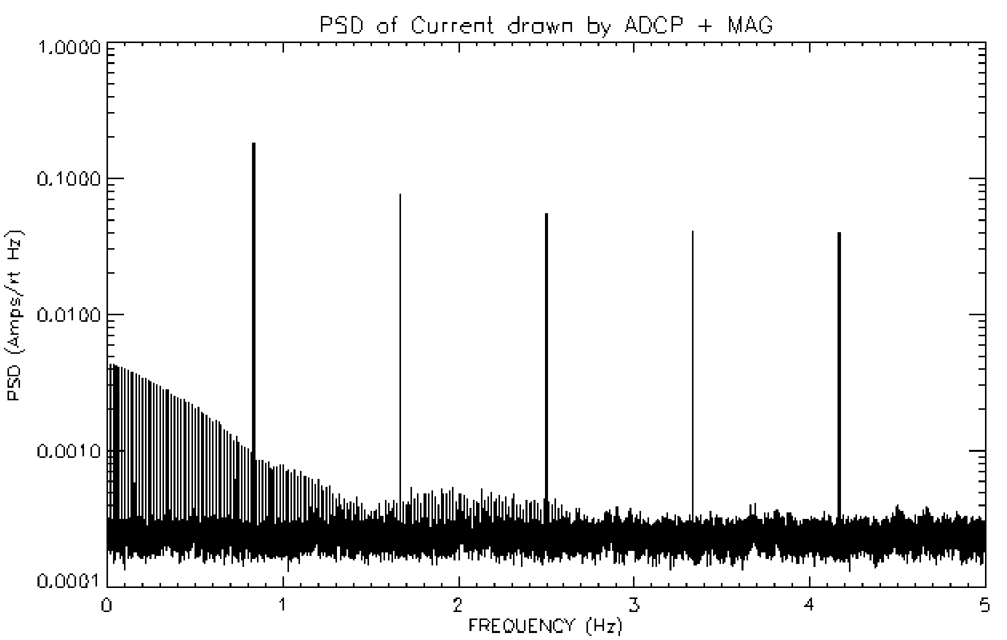
Now let's look at the electrical current draw – with both the ADCP+ mag and with only the mag running.





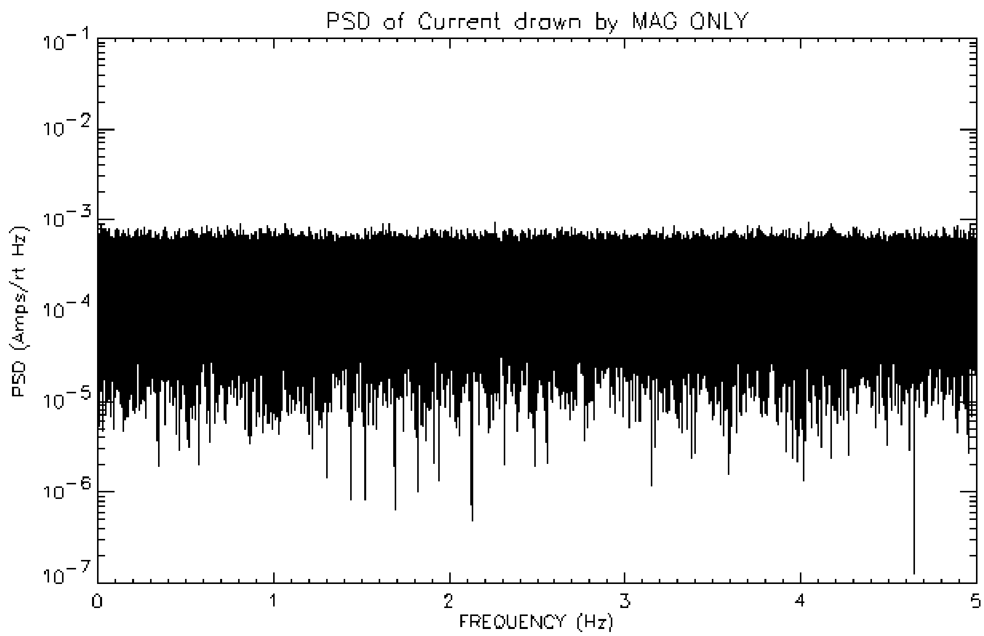
The apparent jump in time is because the files actually start towards the end of the UTC day and start again at zero seconds. There are no missing data points in each file.

There is almost no change in current drawn when only the magnetometer is running, but there is some modulation on the current draw when both the ADCP and magnetometer are running. Here is a plot of the PSD of the ADCP+magnetometer over the first 50000 seconds = 500,000 data points

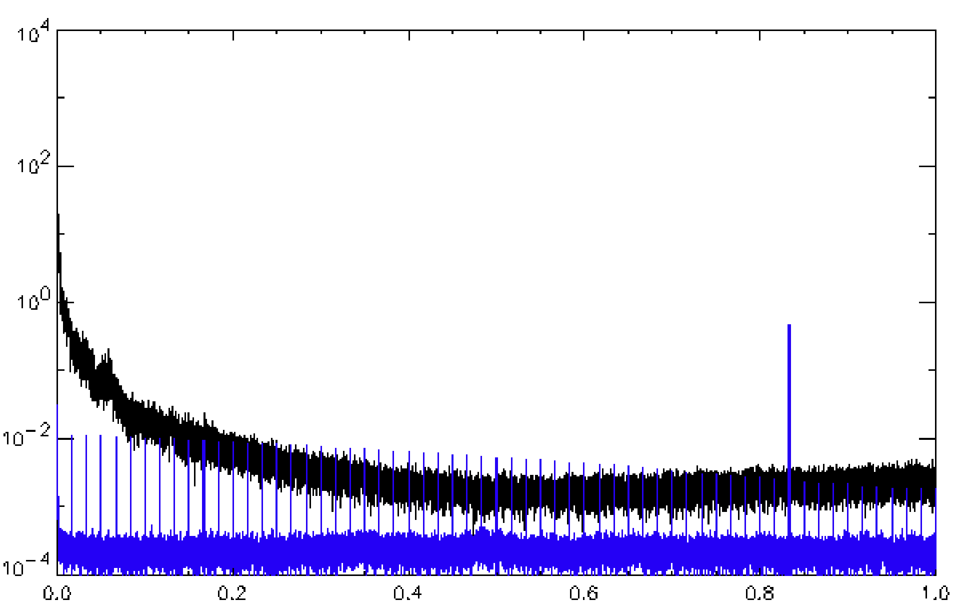


The largest signal is at ~ 0.84 Hz + harmonics. In addition there is a very low frequency signal at 0.0166 Hz (period = 60 seconds), and from the time series one can see that there is a modulation at ~ 10,000 seconds ~ 2.8 hours. However, there is no obvious feature around the 10-20 seconds where we saw anomalies in the Sept 4-7 undersea data.

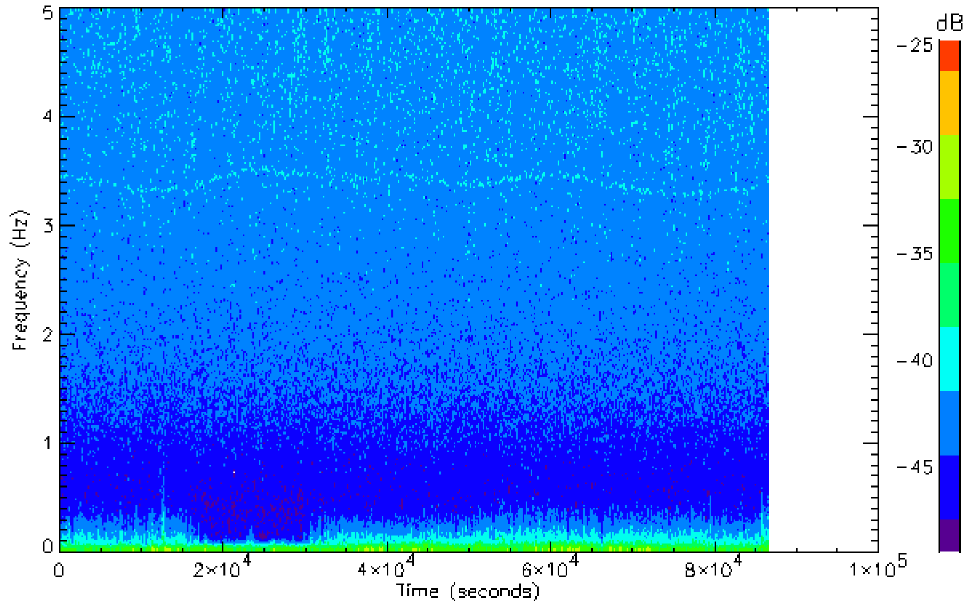
For comparison, here is the PSD of the current drawn by just the magnetometer. This spectrum is flat.



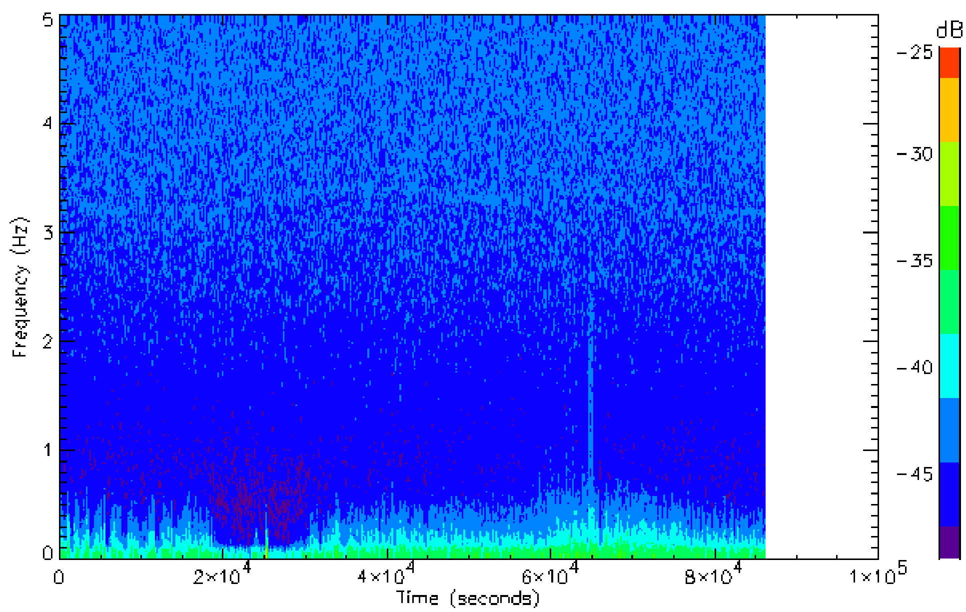
Now let's compare the PSDs of the TF and the Current with ADCP and magnetometer both turned on (800,000 DPS @ 10 Hz used). Clearly there are no features in the PSD of the TF data that correlate with that of the electric current drawn by the ADCP.



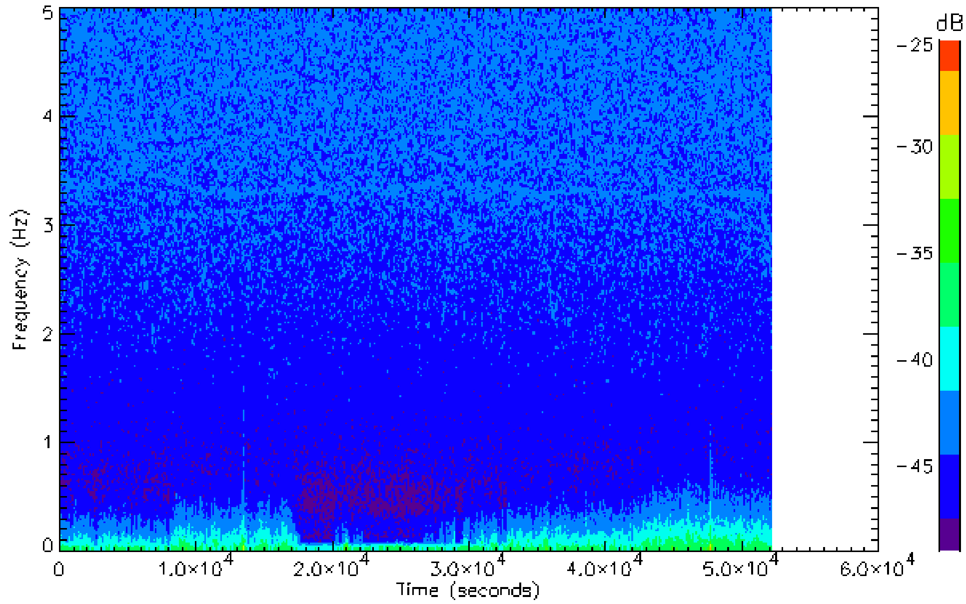
Now let us look at the spectrogram of the TF data for both days.



Note the same quiet section from ~ 16,000 to 30,000 seconds that we saw in the Sept 4-7 data. For example, here is the Sept 7 spectrogram:



Now look at the last day when only the magnetometer was turned on, but not the ADCP. The quiet period occurs at the same time as on the day when both the ADCP and magnetometer were turned on.



This indicates that the apparent quiet period from ~ 18000-30000 seconds that we saw in the Sept 4-7 data is also seen in these data sets too – including when the ADCP power was turned off. Thus the ADCP power is not creating any artifacts in the undersea TF data.

The real issue with the Sept 4-7 data was that we were seeing artifacts on the undersea data with durations of 10-20 seconds that did not correlate with anything seen in the on-shore magnetometer data. We had postulated that it might have been due to the ADCP power, but this does not appear to be the case.

So that leaves actual oceanographic signals as a possibility, or something related to the undersea magnetometer itself. Without the corresponding on-shore data to go with this data set, it is difficult to do much analysis to determine which situation is the case.

Appendix M: Analysis of G824 shorestation data to look for noise artifacts in Nov 17-18 2015 data

Purpose: To look for artifacts in the shorestation magnetic spectra collected at high sampling rate (125 Hz) with the G824 magnetometer that could alias back into the MAD band if a low-sample rate (10 Hz) G823 magnetometer was used.

Data file:
C:\my documents\trials\SFOMF data for NICOP 1\11-18-15 collection (824 next to 823)\puglsey 824 data\com9-20151117161805.log

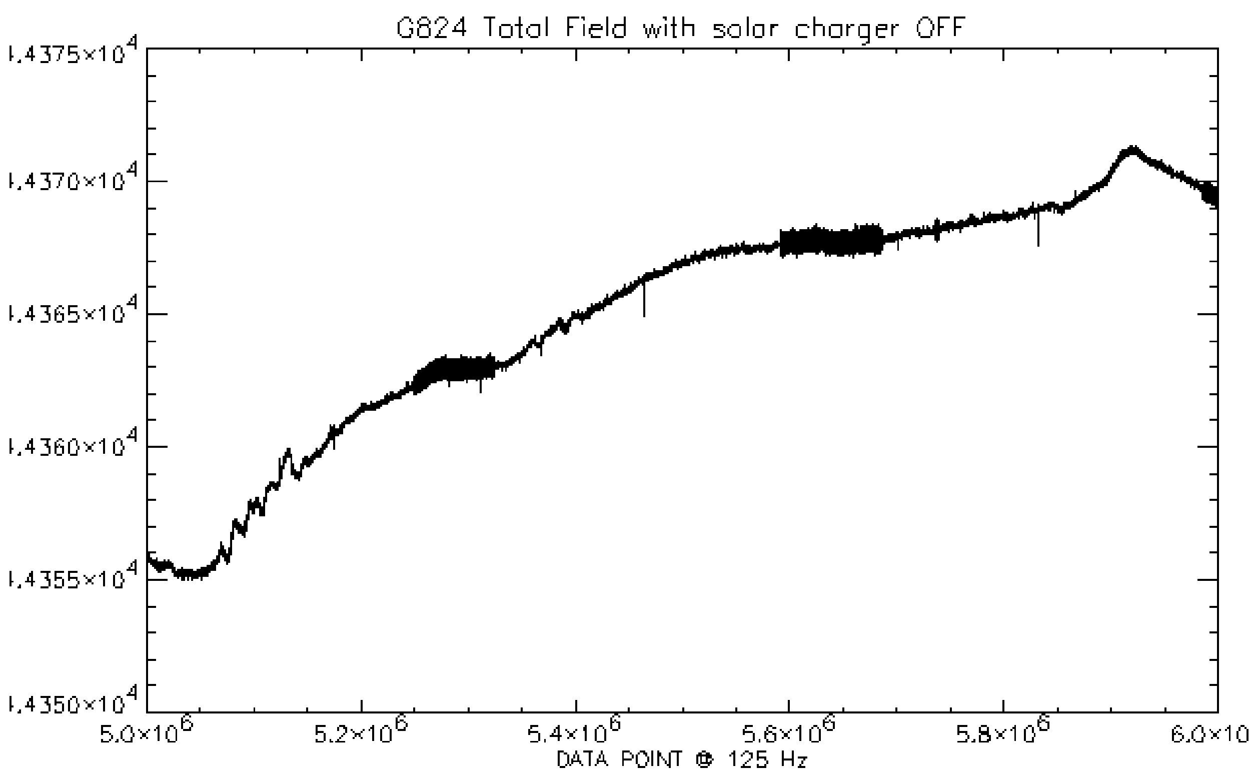
First use dfordPUTTYgeometrics,1,nr,arr,FILEID to read in the raw G24 basestation data. This thrown out the first 50 characters, and only reads the TF data (format d10.4). Use BRADREPAIR to do a linear fit across the one large anomaly in this file. USE WRTFLD to write it back out to

C:\my documents\trials\SFOMF data for NICOP 1\11-18-15 collection (824 next to 823)\puglsey 824 data\com9-20151117161805.log

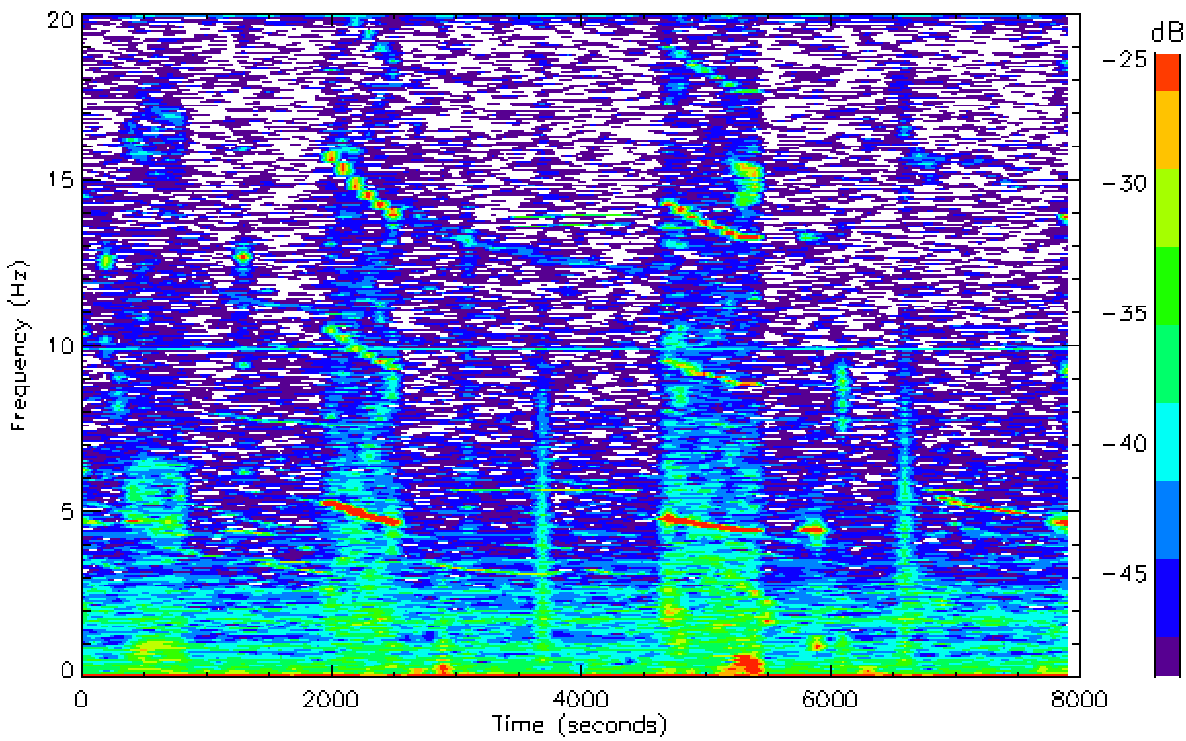
IDL procedure: Use Ft_lauderdale_2015_G824_base_analysis.pro to create these plots.

Data points: Use dpst = 5,000,001 dpend=6,000,000 as this shows some places where the noise levels become larger for a while, then decrease, then increase, then decrease.

Time Series plot over these data points:



Spectrogram over these same data points:



Conclusions:

1) the segments with increased noise begin and end very quickly, just as they do in the G823 data sets.

2) the noise during these segments has a fundamental of ~ 5 Hz, with harmonics near 10 and 15 Hz. However, the frequency slightly changes during the time that it is present.

3) the 10 Hz harmonic will definitely alias back into the MAD band if a G823 magnetometer is used.

4) when that noise is present, there is also wideband noise throughout the 1-20 Hz band.

5) in addition, there appears to be a line at 9.9 Hz that will definitely alias back into the MAD band if a G823 magnetometer is used.

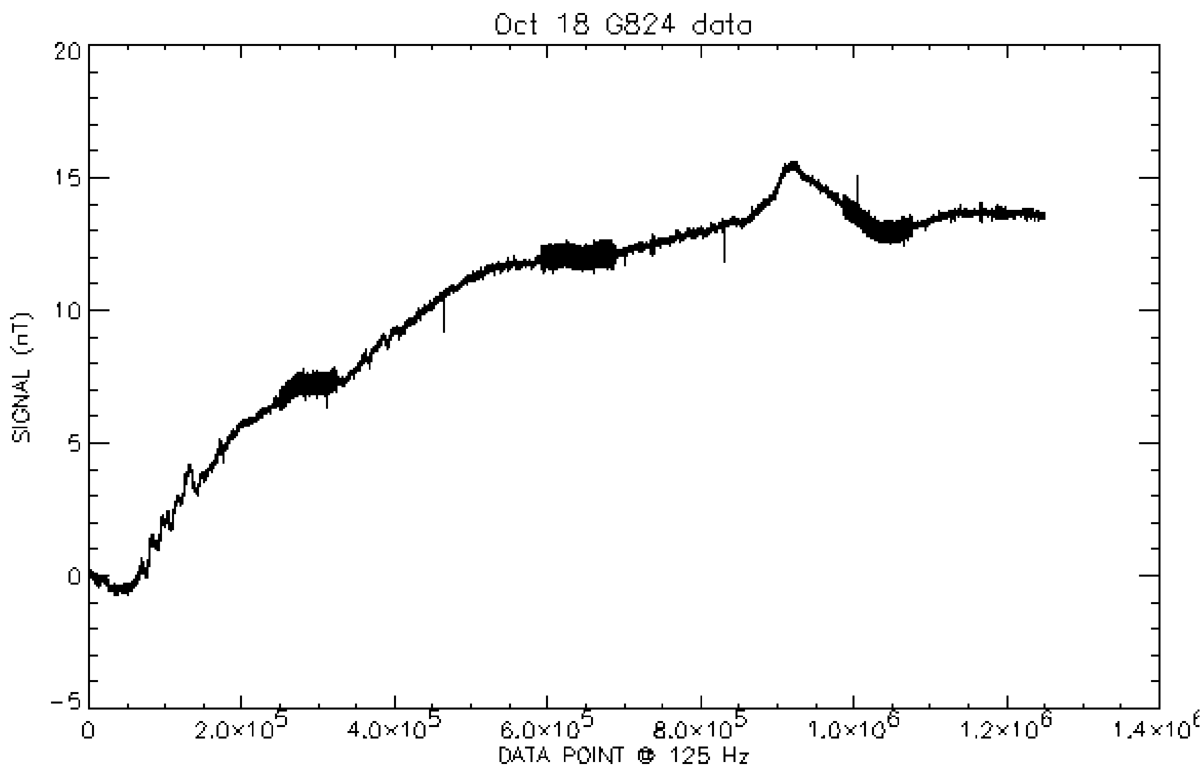
6) the sources of the 5 Hz + harmonics, and the 9.9 Hz line are not known, but there will be LESS total noise aliased into the frequency band of interest if a G824 shorestation magnetometer was used instead of a G823.

Appendix N: Are the noise bursts seen in the Nov 17-18 2015 shorestation data due to the charging station?

Purpose: Determine if the bursts of noise around 4.5-5 Hz (+ harmonics) have the same amplitude on both the G823 magnetometer and the G824 magnetometers.

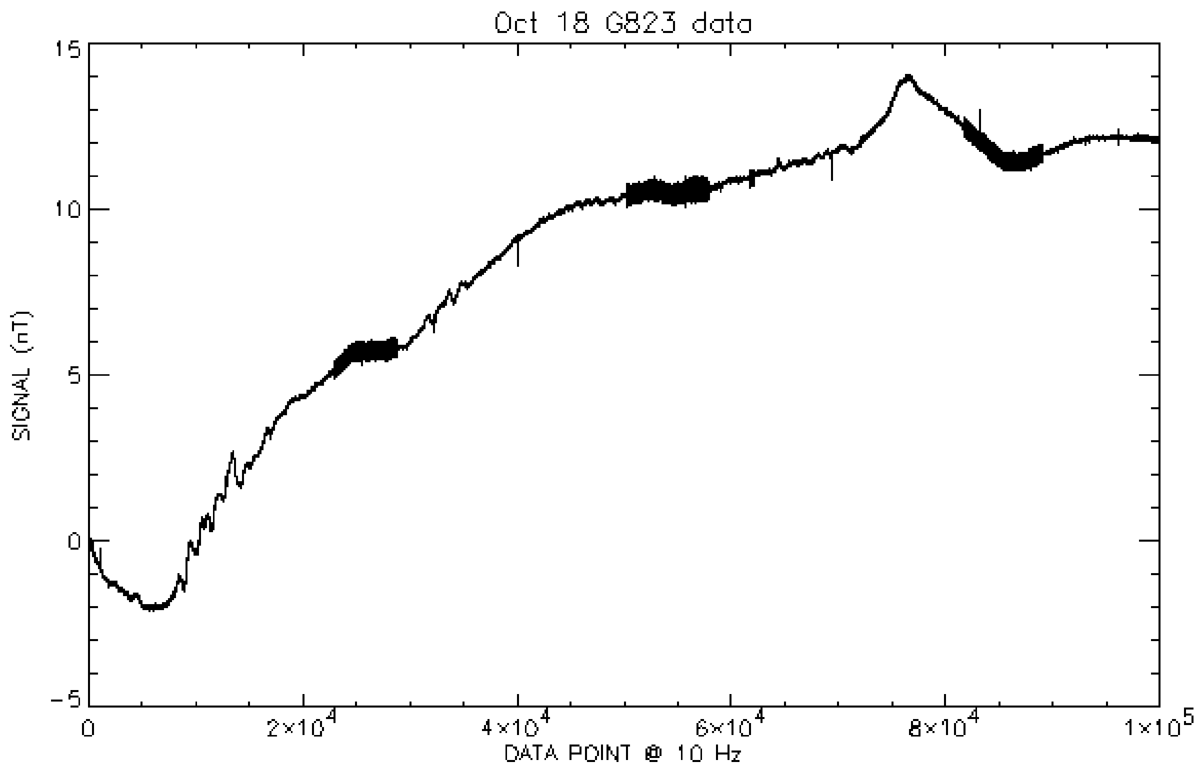
Analysis: Since the G824 sensor is only half the distance from the charging station as the G823, a big discrepancy in the amplitudes could indicate that the noise is coming from the charging station. If the noise is similar in amplitude, this could suggest that the noise is coming from a different environmental source.

Here is a plot of the G824 TF time series with the DC value removed.



The amplitude of the three noise bursts is ~ 0.8 nT peak-to-peak. Note that because of the high sampling rate there is a 60 Hz signal riding on top of the noise burst so the amplitude may be over estimated slightly.

Here is a plot of the G823 TF time series with the DC value removed.



The amplitude of the three noise bursts is ~ 0.65 nT peak-to-peak.

Conclusion: The amplitude of the noise burst measured by the G824 is ~ 0.82 nT while the amplitude of the same noise burst measured with the G823 is ~ 0.65 nT. This is not as large a difference as one would expect if the source of the noise was the charging station, given that the G823 was twice as far from the charging station as the G824.

As a further test, let us look at G823 data collected before the charging station was installed. Here is a plot of G823 data taken on Nov 15, 2014 (file = TOA5_56936_MagData_45_2014_11_15_0000.cor, DP 20000-40000) which was previous analysed in the J. Bradley Nelson, *Analysis of Nov 15 Underwater and Basestation G823 data*, Feb 11, 2015. This clearly shows a similar noise burst of ~ 0.53 nT

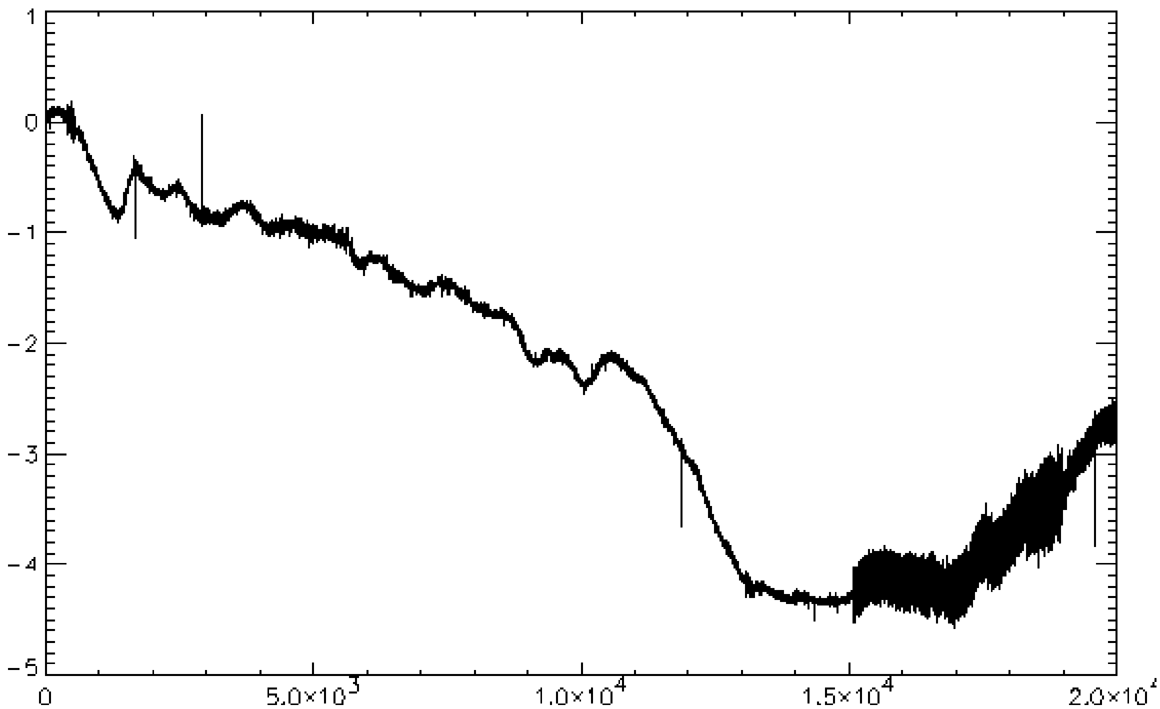


Figure 1 Base TF signal for 20000 dp (= 2000 seconds) on Nov 15, 2014.

<u>Conclusion:</u> Taken together with the previous result, this proves conclusively that the noise bursts are coming from the environment, but they are not due to the charging station.

Appendix O: March 14 2016 basestation analysis: sensor 40 ft away from charger

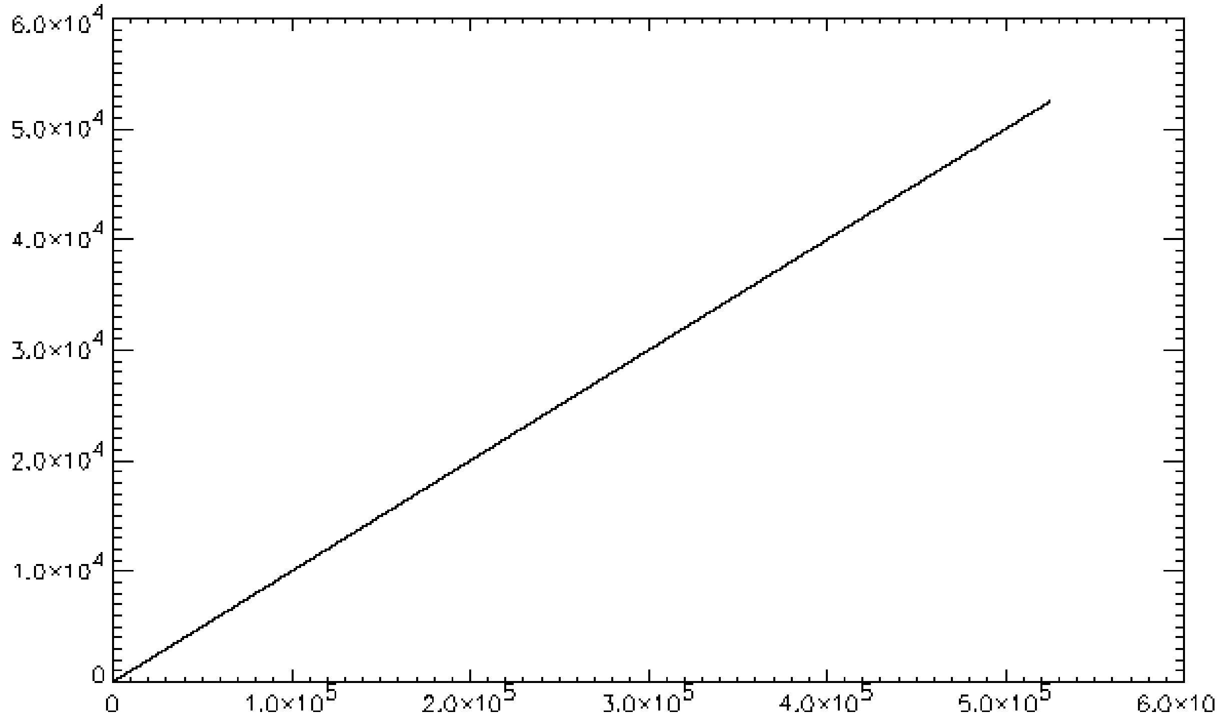
Purpose: Use data from the first portion of the day, when the data was being sent automatically to NSWC to determine the noise levels when the sensor was 40 ft from the charging unit.

Data file: 'C:\my documents\trials\SFOMF data for NICOP 1\Mar 2016\TOA5_56936_MagData_96.dat'

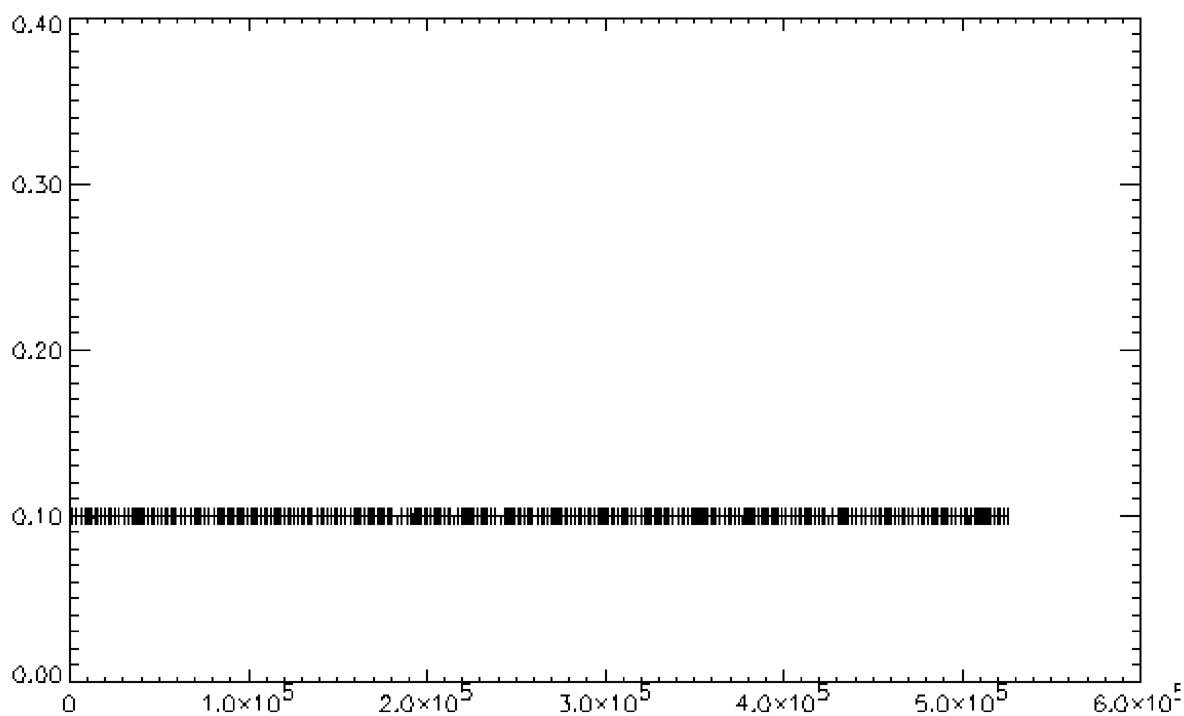
IDL routine: SFOMFbase_Mar14_2016.pro

Results:

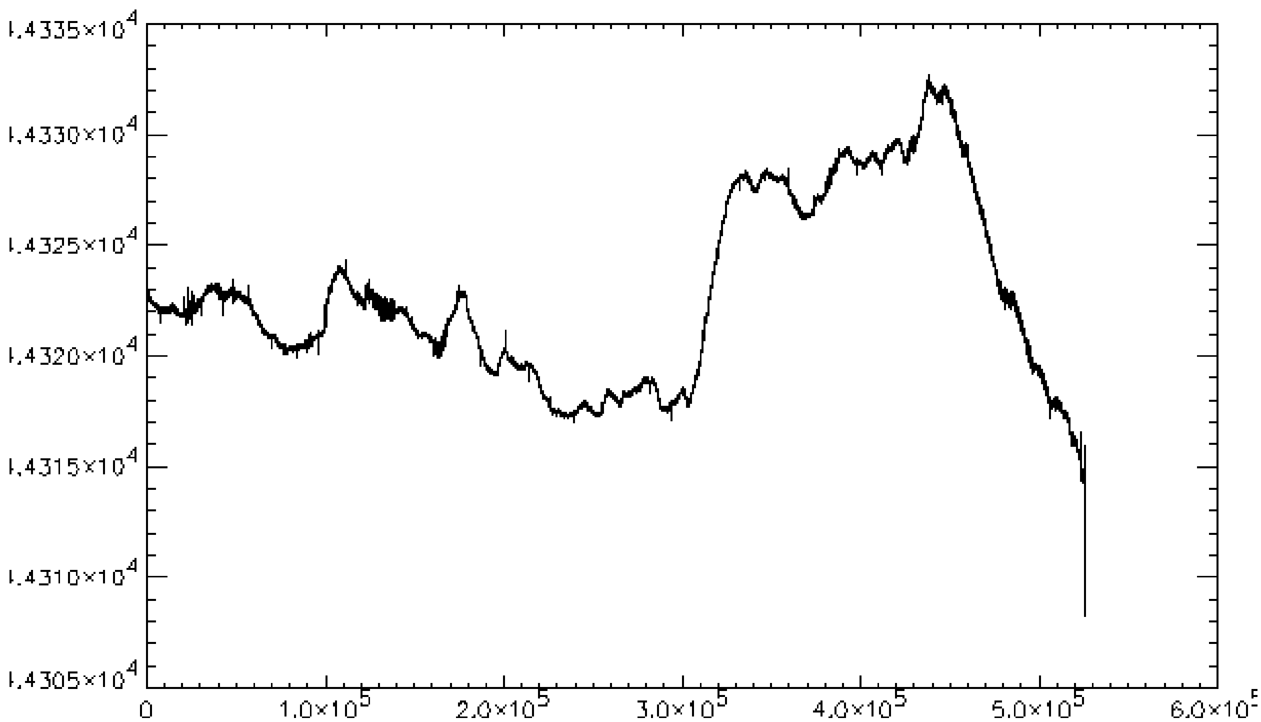
Time plot:



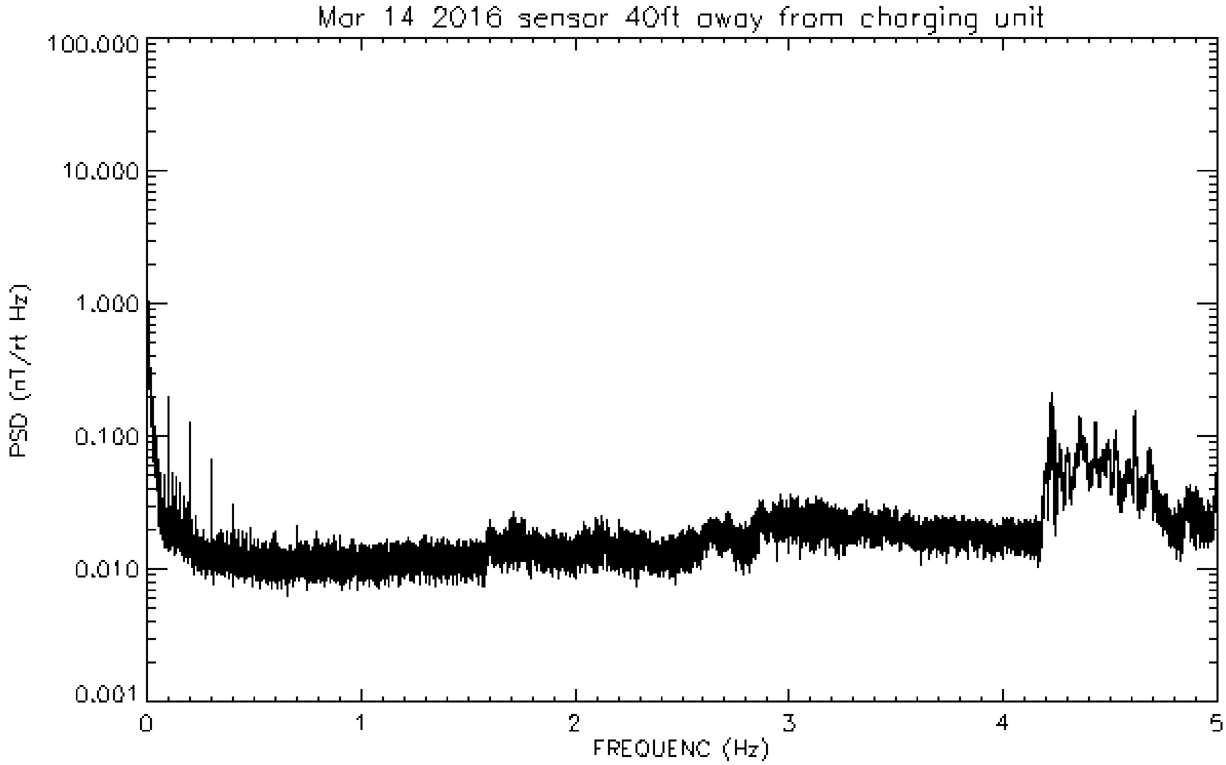
Deriv of Time plot:

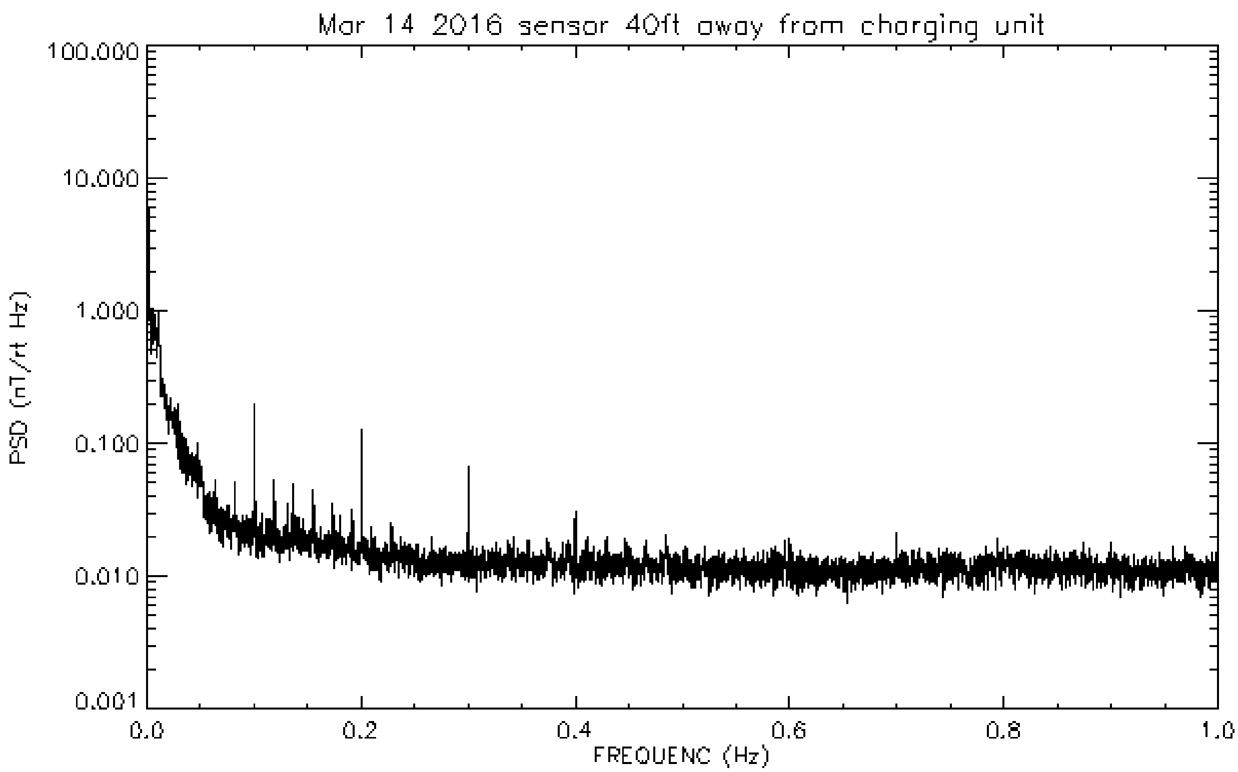


Total field plot:

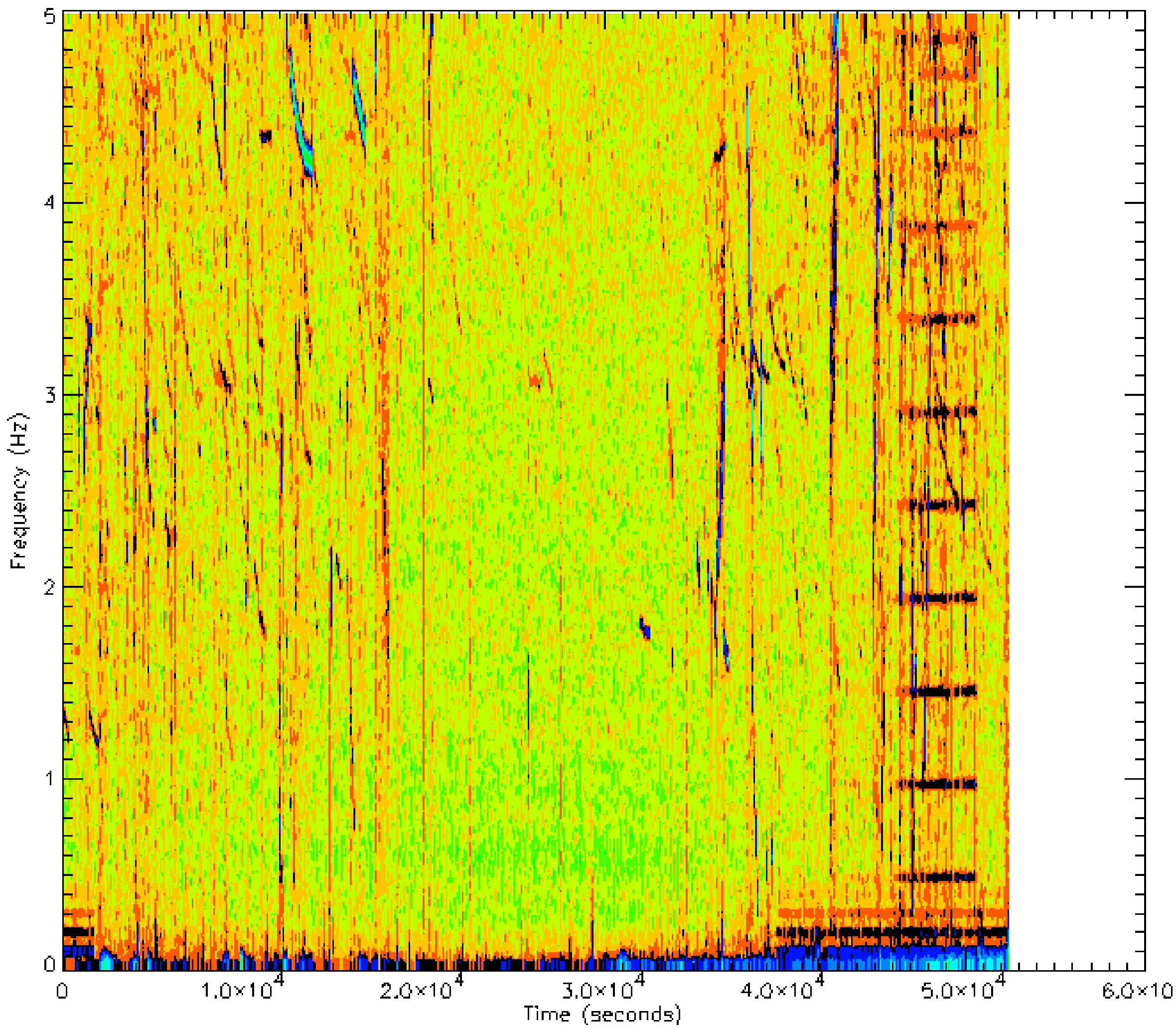


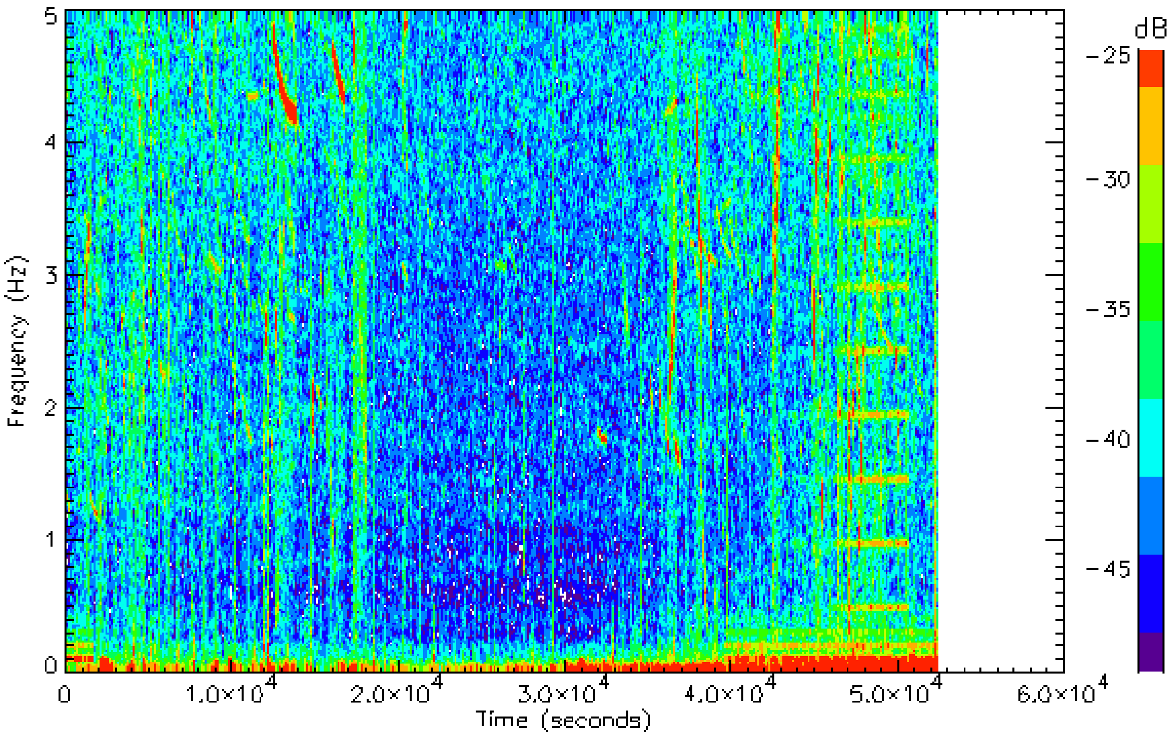
Use dp 1001-501000 for PSD.





Here is the spectrogram





Conclusions:

1) There are no missing data points as there is ~ 0.1 seconds between data points.

2) The white noise level is ~ 10-15 pT/rt Hz down to ~ 0.1 Hz.

3) There is geomagnetic activity below that.

4) The 0.5 Hz + harmonics shows up at ~ 45000 seconds into the file. This is due to the charging system. For comparison, the _97 file (when the magnetometer was 100 ft away) does not contain any of these 0.5 + harmonics signals.

5) However, there are lines at 0.1 Hz + harmonics that occur for ~ first 2000 seconds and from 39000 seconds to the end of the file. It is not clear where these lines come from BUT, the amplitude of those lines is about the same when the magnetometer was 40 ft away from the charger as when it was 100 ft away. Thus I conclude that the 0.1 Hz + harmonics are NOT due to the charging unit.

6) The 4.5 Hz line also shows up at ~ 12000-16000 seconds. Again, I believe this in environmental, not due to the charging system because it was found in old data sets when the charger was being used, and on the G824 magnetometer in the November 2015 data sets.

7) There are also lines @ 0.047, 0.064, 0.082, etc. These lines are smaller and appear to be harmonics of ~ 0.016 Hz which is ~ 1 minute period. Their original is unknown, but they were not present when the sensor was 100 ft away from the charger. These lines show up for almost the entire file whereas the 0.1

Hz + harmonics only show up from time 0-2000 seconds and 39000s to the end of the file. Thus the 1 minute period signals don't appear to be due to the same source as the 0.1 Hz + harmonic signals.

Appendix P: March 14 2016 basestation analysis: sensor 100 ft away from charger

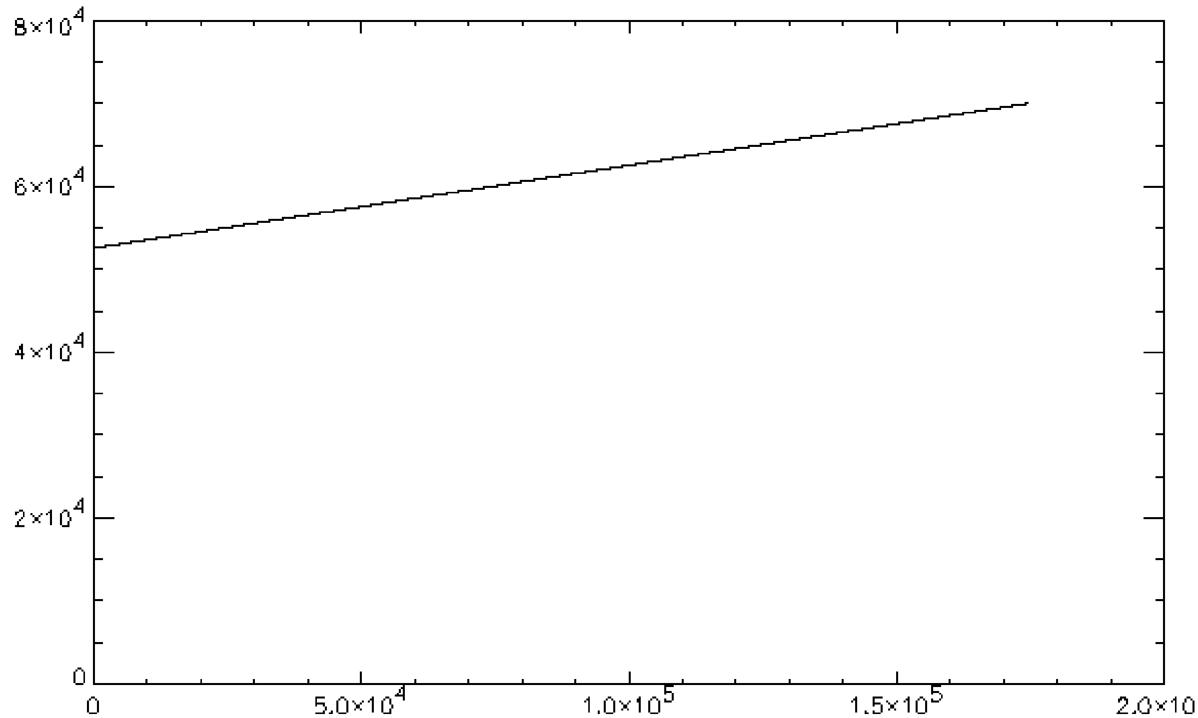
Purpose: Move the magnetometer to 100 ft away from the charging unit and collect data to the flash drive. Compare the noise spectrum to that measured with the sensor at 40 ft away.

Data file: 'C:\my documents\trials\SFOMF data for NICOP 1\Mar 2016\TOA5_56936_MagData_97.dat'

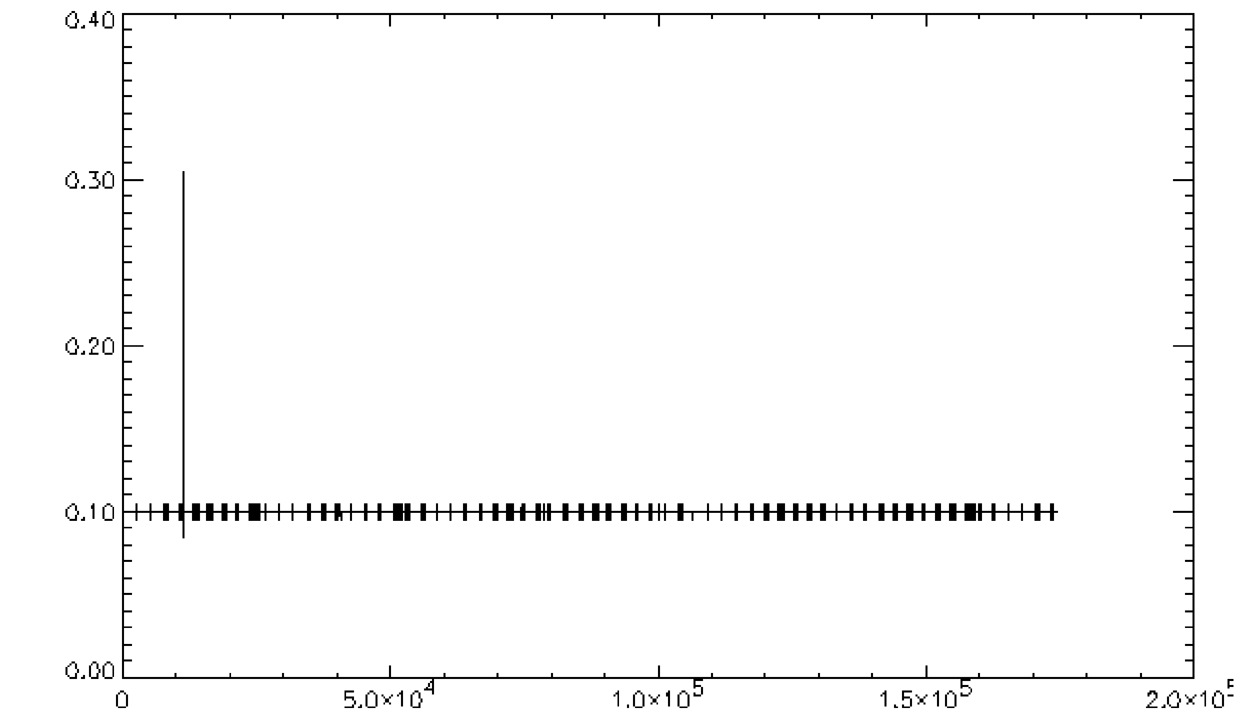
IDL routine: SFOMFbase_Mar14_2016.pro

Results:

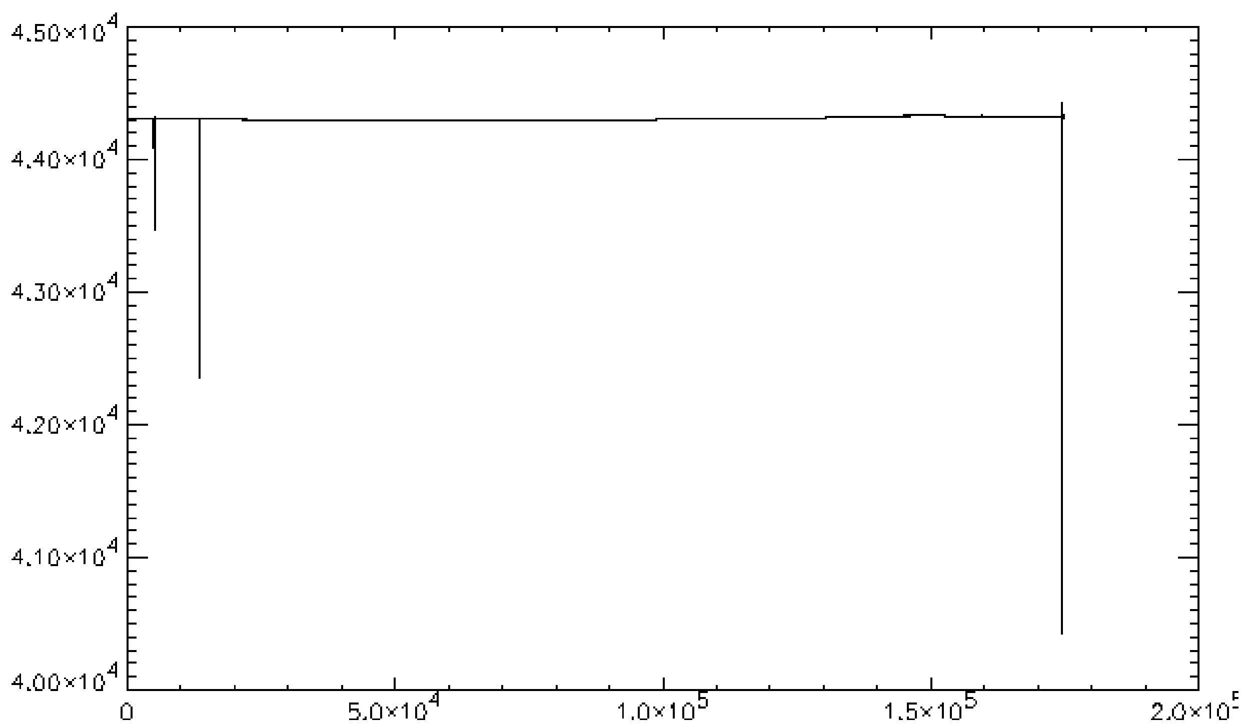
Time plot:

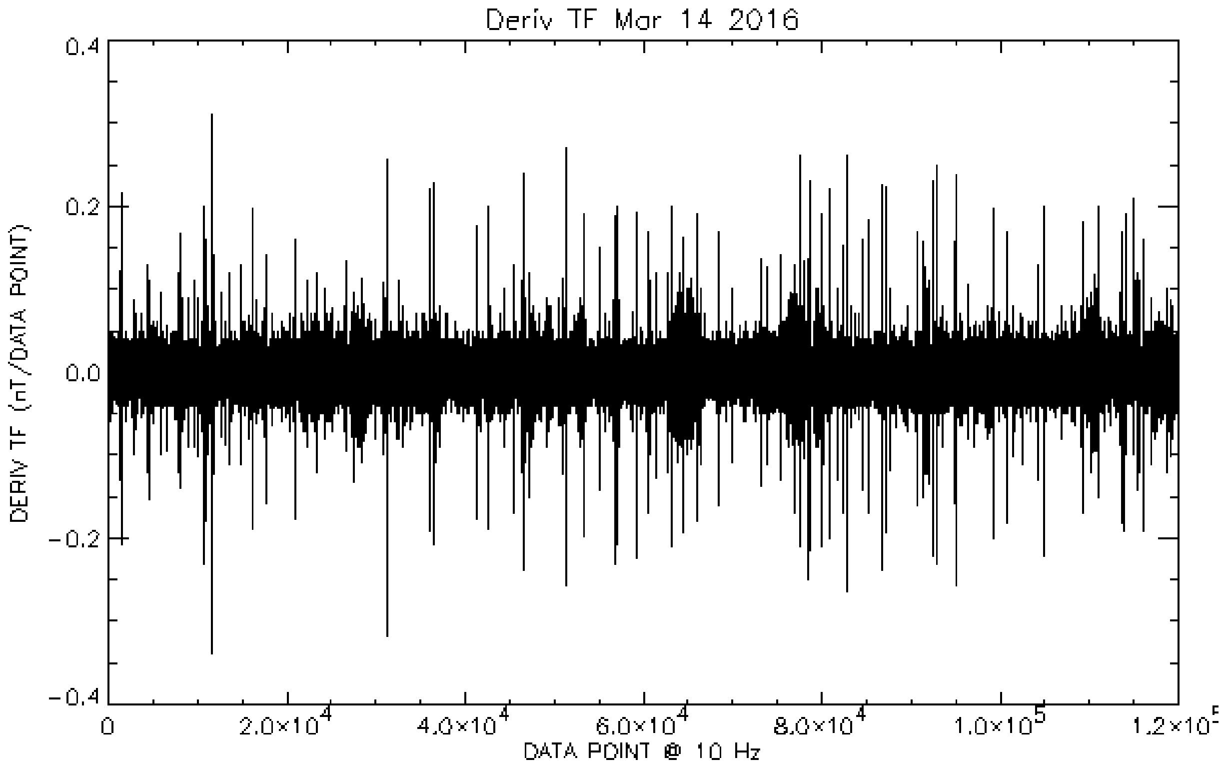


Deriv of Time plot:

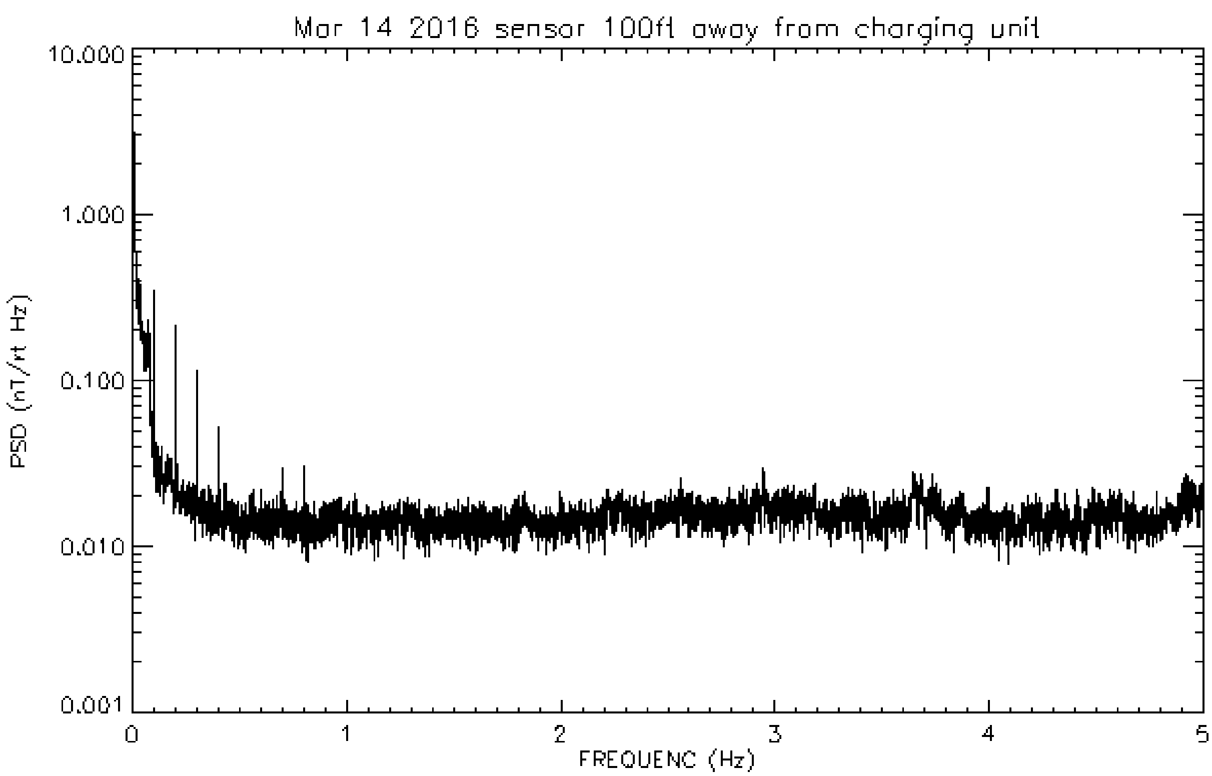


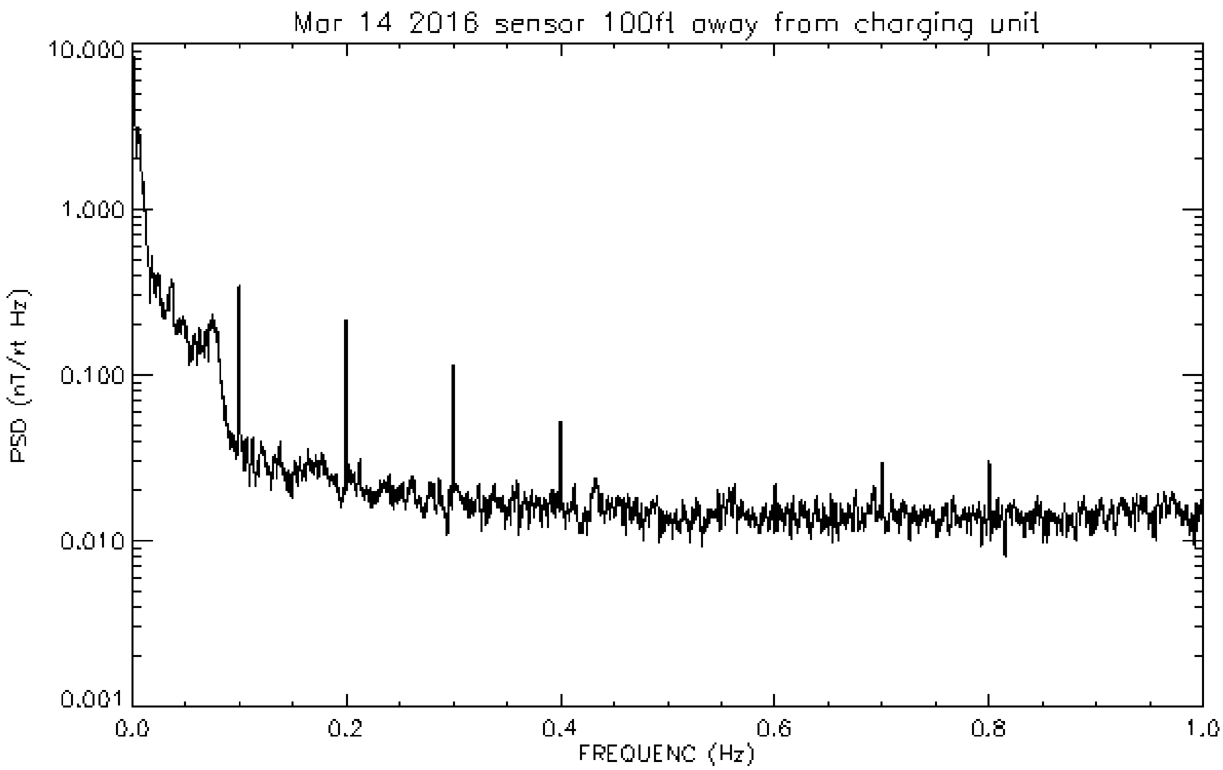
Total field and Deriv of TF plots:



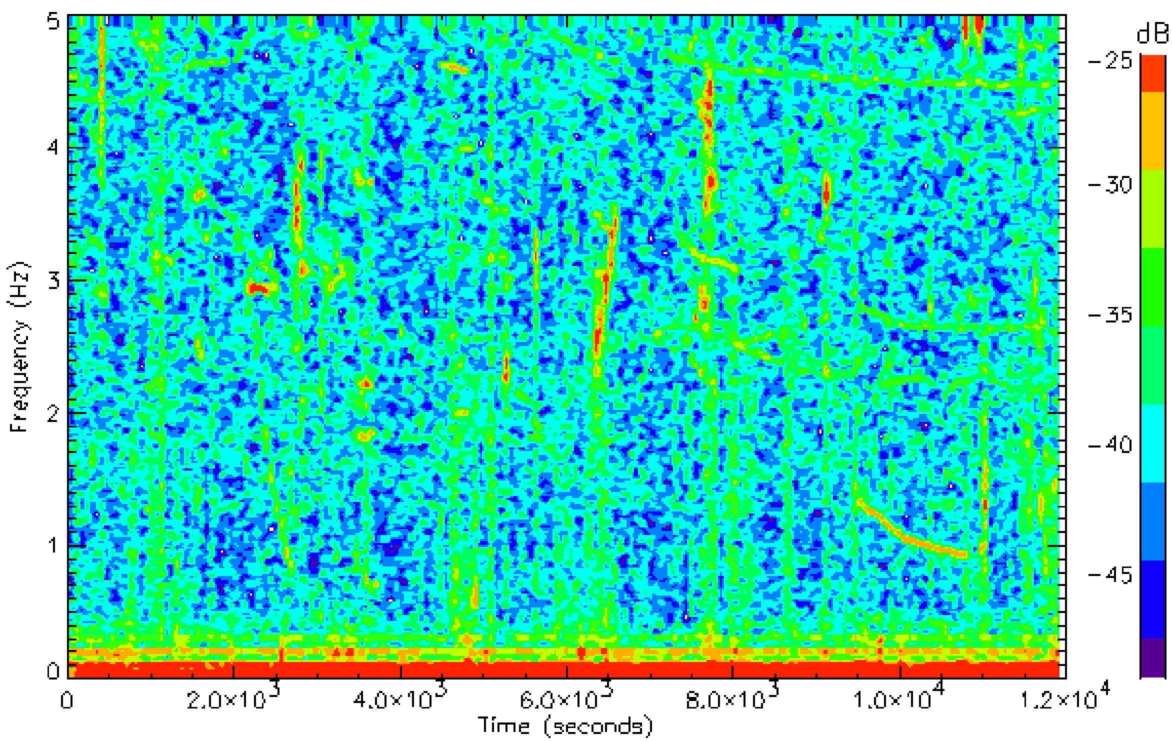


Use dp 30001-150000 for PSD.





Here is the spectrogram:



Conclusions:

1) The white noise level is about 20 pT/rt Hz starting near 0.15 Hz. This is as expected.

2) The geomagnetic signal is < 0.1 Hz as expected.

3) There are discrete lines at 0.1, .2, .3, .4. .7, and .8 Hz. The source of these lines is unknown.

4) The charging noise at 0.5 Hz + harmonics is not present, or at least is below the 15 pT/rt Hz white noise level above 0.5 Hz.

5) There seem to be many small glitches (see the Deriv TF plot), but again this is fairly common in previous data sets. However, there isn't much noise at 4-5 Hz. Perhaps the data set was too short to see these bursts.

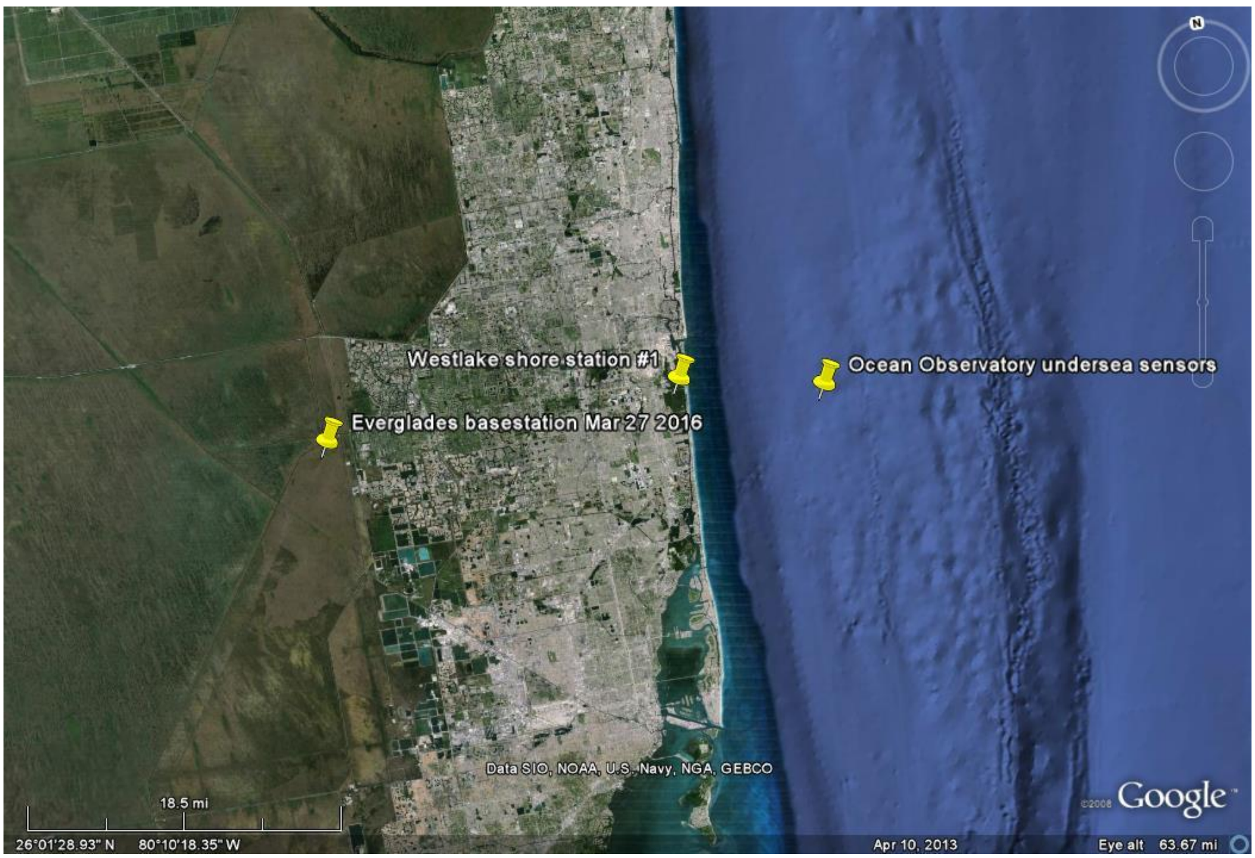
Appendix Q: Analysis of Mar 17 2016 everglades.txt

Purpose: collect ~ 10 minutes of data @ 250 Hz. Baud = 230400 using REALTERM.exe and the FTDI F36 RS232-USB adapter. Location = South Florida Water Management District canal, ~ 2 miles from the Holiday Park Recreation Area along the berm that runs along the minor canal. This is the eastern of the two canals.

Method: Remove the 1st and last lines in the file and replace $ sp sp with sp.

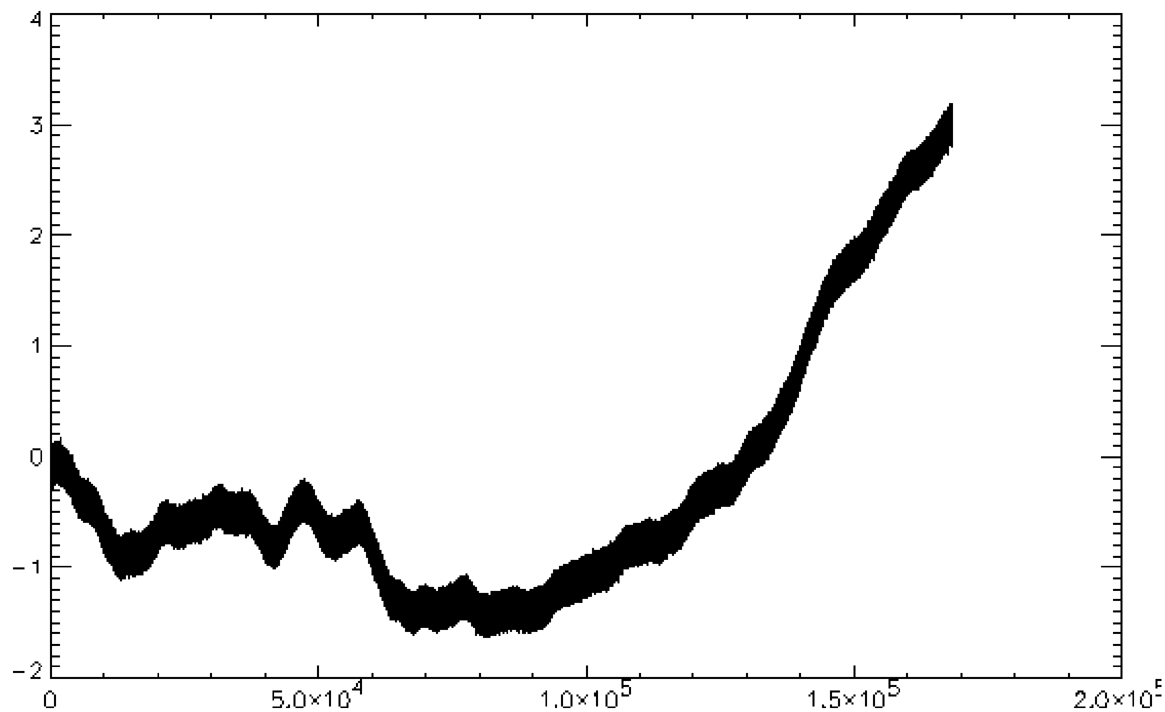
Dford,4,nr,a,file
Colext,a,tf,0

Results: The following plot shows the location of the Everglades site relative to the Westlake basestation and undersea magnetometer locations.

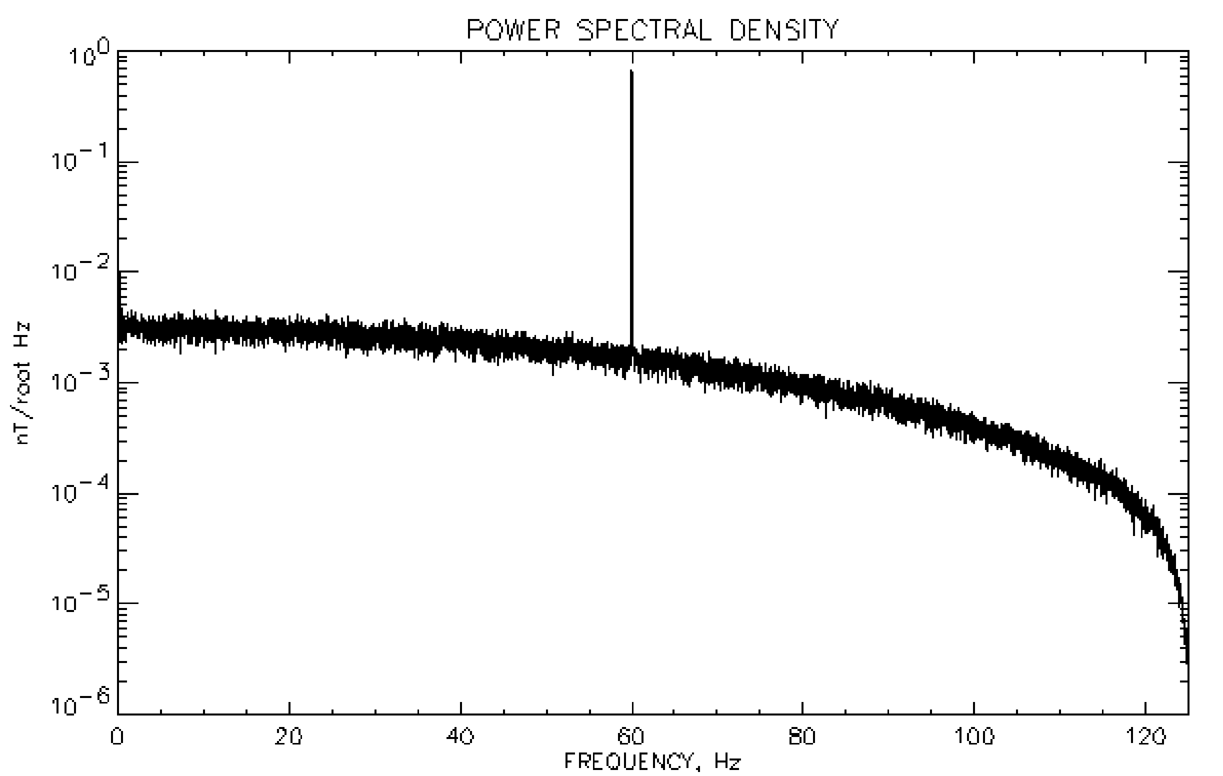


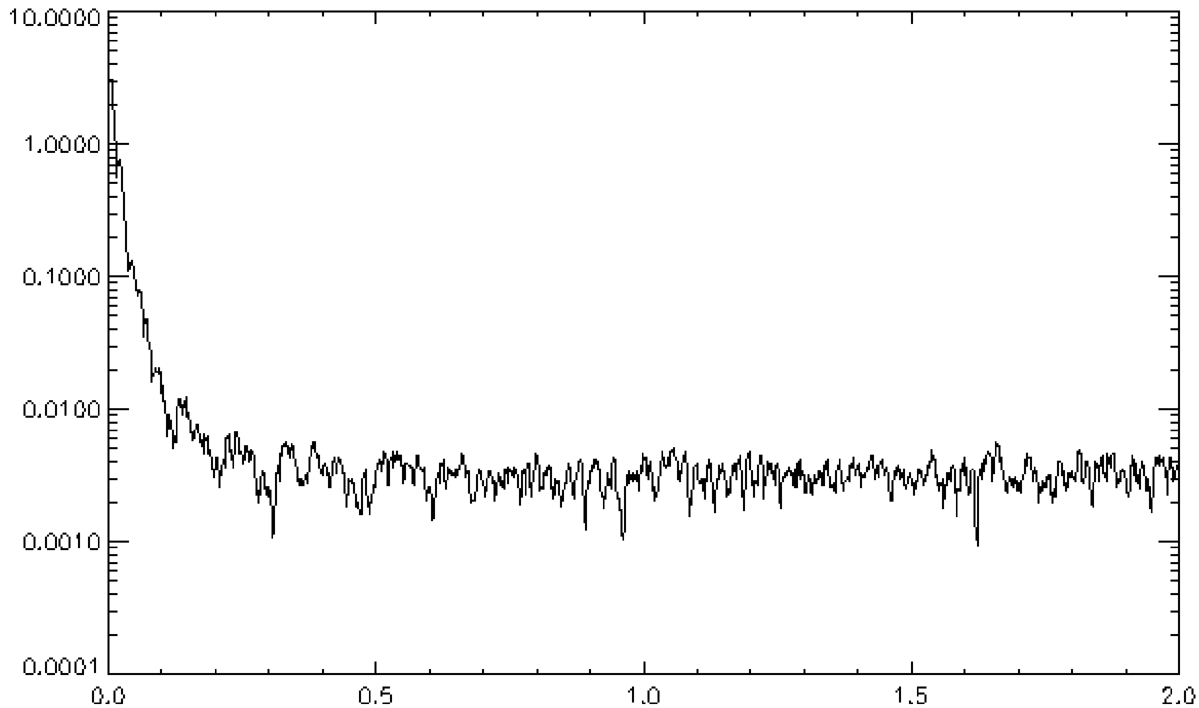
Location of Everglades basestation relative to the Westlake basestation and undersea sensors.

Plot of TF with first value removed showing 60 Hz is about 0.3 nT in amplitude.



PSD plot:





<u>Conclusions:</u>

1) White noise @ 0.2 Hz is 4 pT/rt Hz
2) No obvious features other than the 60 Hz.

Appendix R: Analysis of March 17 2016 undersea, Westlake, and Everglades data

Purpose: Compare the magnetic fields measured at the three sites, calculate the coherence vs. frequency for each pair of sites, and calculate the noise reduction possible for Undersea vs. Westlake and Undersea vs. Everglades basestations.

Files:
C:\my documents\trials\SFOMF data for NICOP 1\Mar 2016\everglades comparison data\West lake mag\TOA5_56936_MagData_99.dat

C:\my documents\trials\SFOMF data for NICOP 1\Mar 2016\Mar 17 2016 everglades.txt

C:\my documents\trials\SFOMF data for NICOP 1\Mar 2016\everglades comparison data\UW-mag (new format)\20160315 - Node 1 Mag.txt

IDL routine: compare_everglades_westlake_offshore_Mar15.pro (see below)

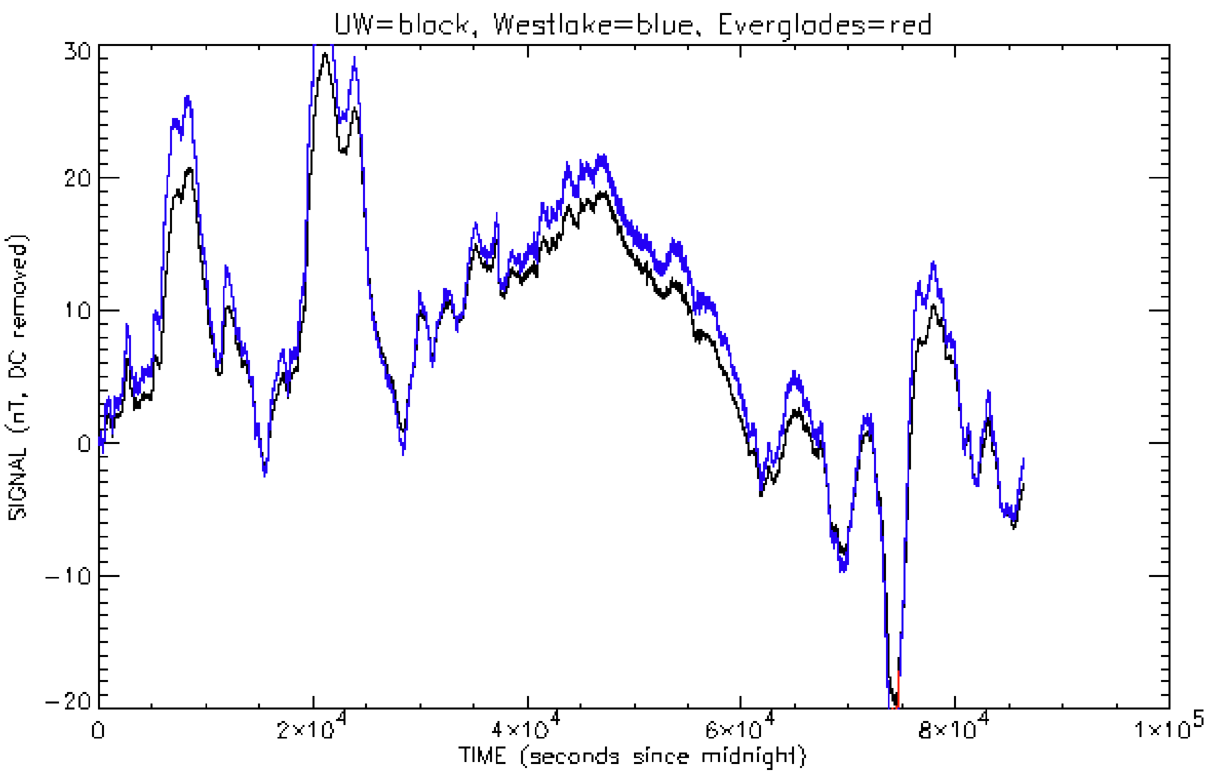
```
pro compare_everglades_westlake_offshore_Mar15
;
; read in the three files and do the comparison
;
initial
filewestlake='C:\my documents\trials\SFOMF data for NICOP 1\Mar 2016\everglades comparison
data\West lake mag\TOA5_56936_MagData_99.dat'  ;use ReadBaseStationMag,filein,tim,mag1
ReadBaseStationMag,filewestlake,timw,magw &timw=timw(0:864030) &magw=magw(0:864030)
;
fileeverglades='C:\my documents\trials\SFOMF data for NICOP 1\Mar 2016\Mar 17 2016 everglades.txt'
;use dford,4,nr,a,file
dford,4,nr,ever,fileeverglades
colext,ever,evertf,0
dum=smooth(evertf,51) &n=size(evertf) &x=findgen(n(1)/25.)*25. &evertf10=dum(x) &q=size(evertf10)
&dp=q(1)
timever=dindgen(dp)*0.1+74059.10   ; this comes from the correlation analysis below
;
;   used to be 74280-200-22.0+3.6-2.5
;
fileuw='C:\my documents\trials\SFOMF data for NICOP 1\Mar 2016\everglades comparison data\UW-
mag (new format)\20160315 - Node 1 Mag.txt' ; use ReadBaseStationMag,filein,tim,mag1
Read_SFOMF_undersea_March_2016,fileuw,timuw,maguw &timuw=timuw(0:864028)
&maguw=maguw(0:864028)
;
window,0
plot,timuw,maguw-maguw(0),xtitle='TIME (seconds since midnight)',ytitle='SIGNAL (nT, DC
removed)',title='UW=black, Westlake=blue, Everglades=red'
oplot,timw,magw-magw(0),color=50
```

```
oplot,timever,evertf10-evertf10(0)-20,color=230
;
; now filter each with a 0.02 HP Hz filter
;
bpfax,10,0.02,1,maguw-maguw(0),maguwbp
bpfax,10,0.02,1,magw-magw(0),magwbp
bpfax,10,0.02,1,evertf10-evertf10(0),evertf10bp
;
time=timever(200:*)
spak,timuw,maguwbp,time,UW
spak,timw,magwbp,time,W
spak,timever,evertf10bp,time,EVER
;
lag=findgen(200)-100.
Res = C_CORRELATE( W, EVER, Lag)
;
window,1
plot,lag,res,xrange=[-50,50],/ynoz
;
;now do a frequency-domain cancelation to get the coherence
;
window,2
Cancel_1cmp, 10, W, EVER, 5, SyyDB, SnnDB, GW_EVER, ntW_EVER, 1
Cancel_1cmp, 10, W, UW, 5, SyyDB, SnnDB, GW_UW, ntW_UW, 1
Cancel_1cmp, 10, EVER,UW, 5, SyyDB, SnnDB, GEVER_UW, ntEVER_UW, 1
;
psdsr,10,EVER,f,pEVER,sm=5
psdsr,10,UW,f,pUW,sm=5
psdsr,10,W,f,pW,sm=5
psdsr,10,ntW_EVER,f,pntW_EVER,sm=5
psdsr,10,ntW_UW,f,pntW_UW,sm=5
psdsr,10,ntEVER_UW,f,pntEVER_UW,sm=5
;
plot_io,f,pUW,xtitle='FREQUENCY (Hz)',ytitle='PSD (nT/rt Hz)',title='UW=black, Westlake=blue,
Everglades=red'
oplot,f,pW,color=50
oplot,f,pEVER,color=230
;
window,4
plot_io,f,pUW,xtitle='FREQUENCY (Hz)',ytitle='PSD (nT/rt Hz)',title='UW=black, Res vs Westlake=blue,
Res vs Everglades=red'
oplot,f,pntW_UW,color=50
oplot,f,pntEVER_UW,color=230
;
; now lot the coherence of each
;
window,5
```

```
plot,f,smooth(GW_EVER,5),xtitle='FREQUENCY (Hz)',ytitle='Coherence',title='Coherence of W vs.
EVER=black, W vs. UW=blue, EVER vs UW=red',xrange=[0,0.2]
oplot,f,smooth(GW_UW,5),color=50
oplot,f,smooth(GEVER_UW,5),color=230
;
window,6
plot_io,f,pUW,xtitle='FREQUENCY (Hz)',ytitle='PSD (nT/rt Hz)',title='UW=black, Res vs Westlake=blue,
Res vs Everglades=red',xrange=[0,0.2]
oplot,f,pntW_UW,color=50
oplot,f,pntEVER_UW,color=230
;
return
end
```

Analysis:

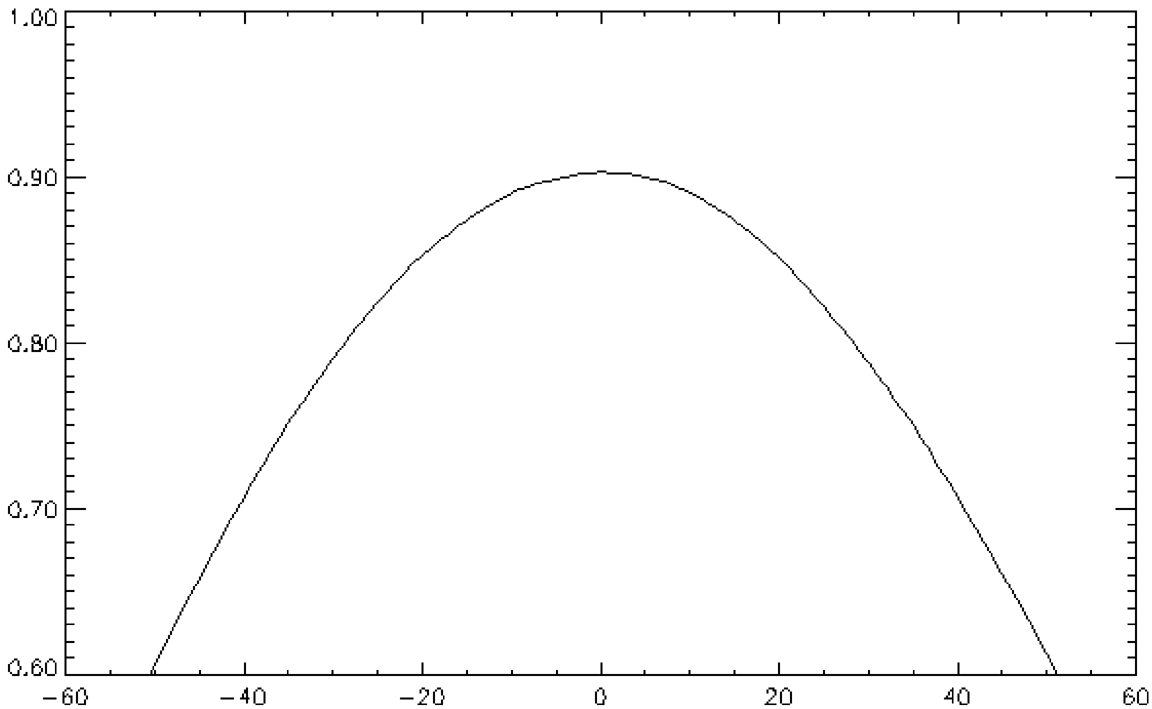
Here is a stack plot of time vs. TF for the 3 files. The DC offsets have been removed and the Everglades data had -20 nT added to make it easier to see the correlation.



As there was no timestamp on the Everglades data, a correlation method was used to determine what the timestamp should have been to obtain the highest correlation coefficient. That time was determined to be:

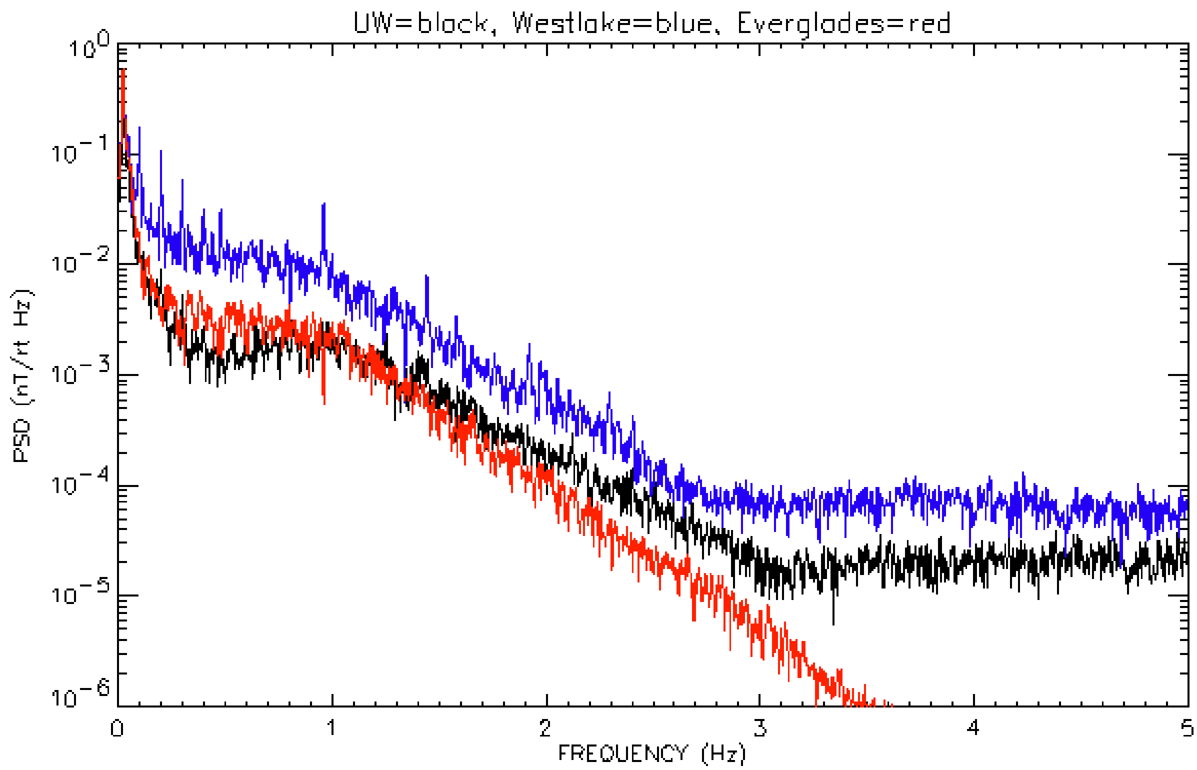
Time Everglades = (0.004 * data point value) + (74280-200.0-22.0+3.6) seconds

The following plot shows the correlation coefficient vs. lag – since the peak is at a lag of zero this means that I have chosen the correct timestamp.

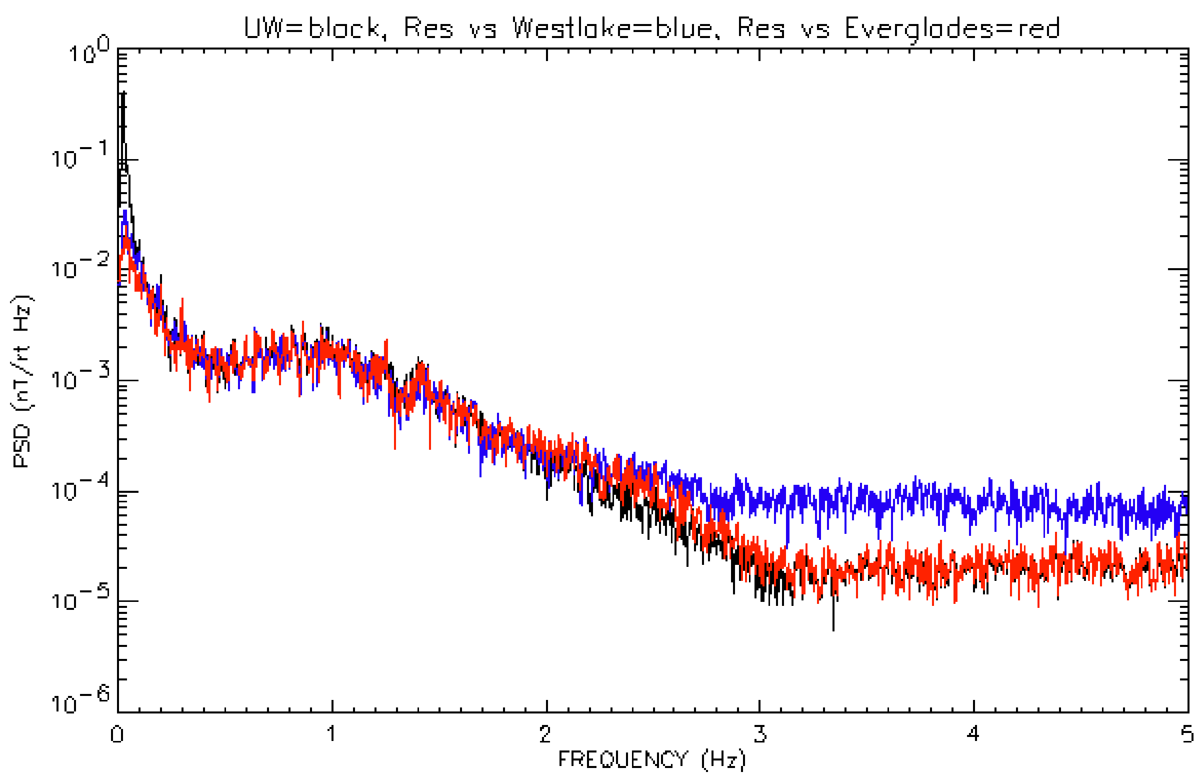


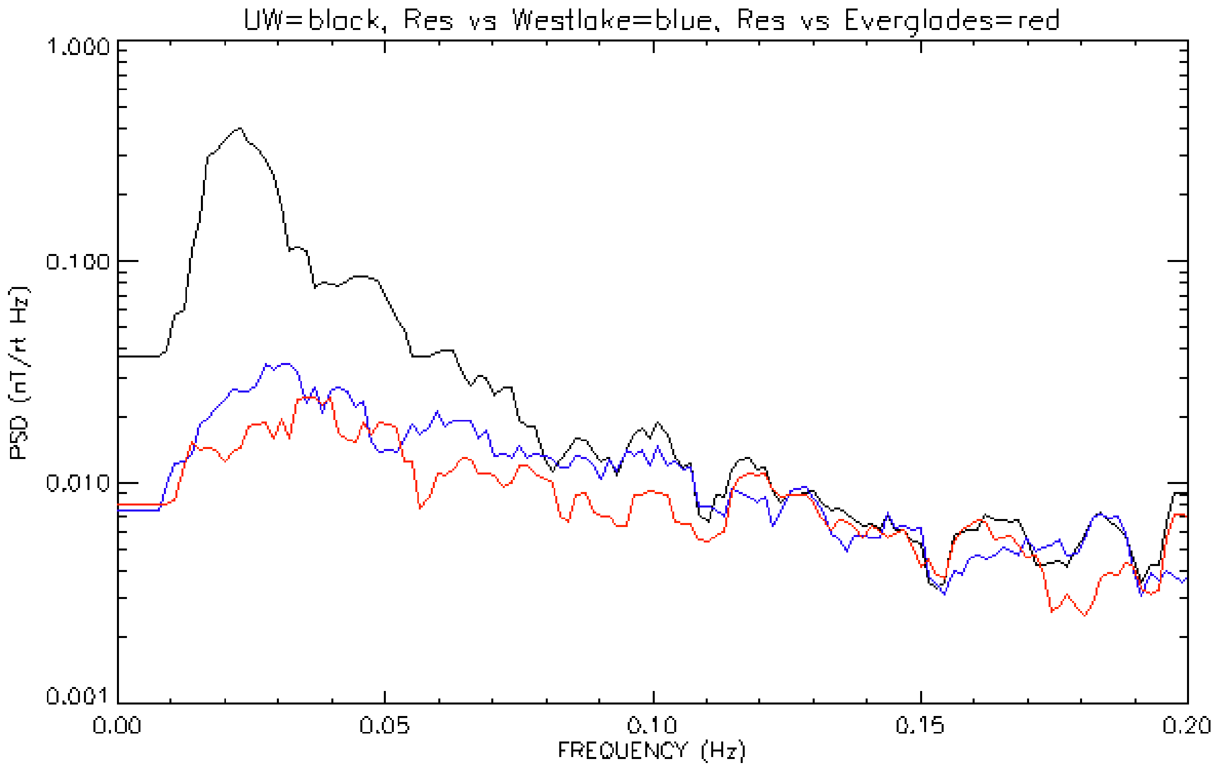
Each of the three time series was then band-pass filtered at band-pass filtered from 0.02-1 Hz with a 4th-order Bessel filter and re-sampled at 10 Hz starting at 74061.600 seconds since midnight and ending at 74734.800 seconds. This yielded three aligned time series denoted UW = undersea, W = Westlake basestation, and EVER = Everglades basestation. Power spectra and Coherence/Cancellation processing was done on these band-pass -filtered time series

The next plot shows the PSDs of the three band-pass filtered signals.

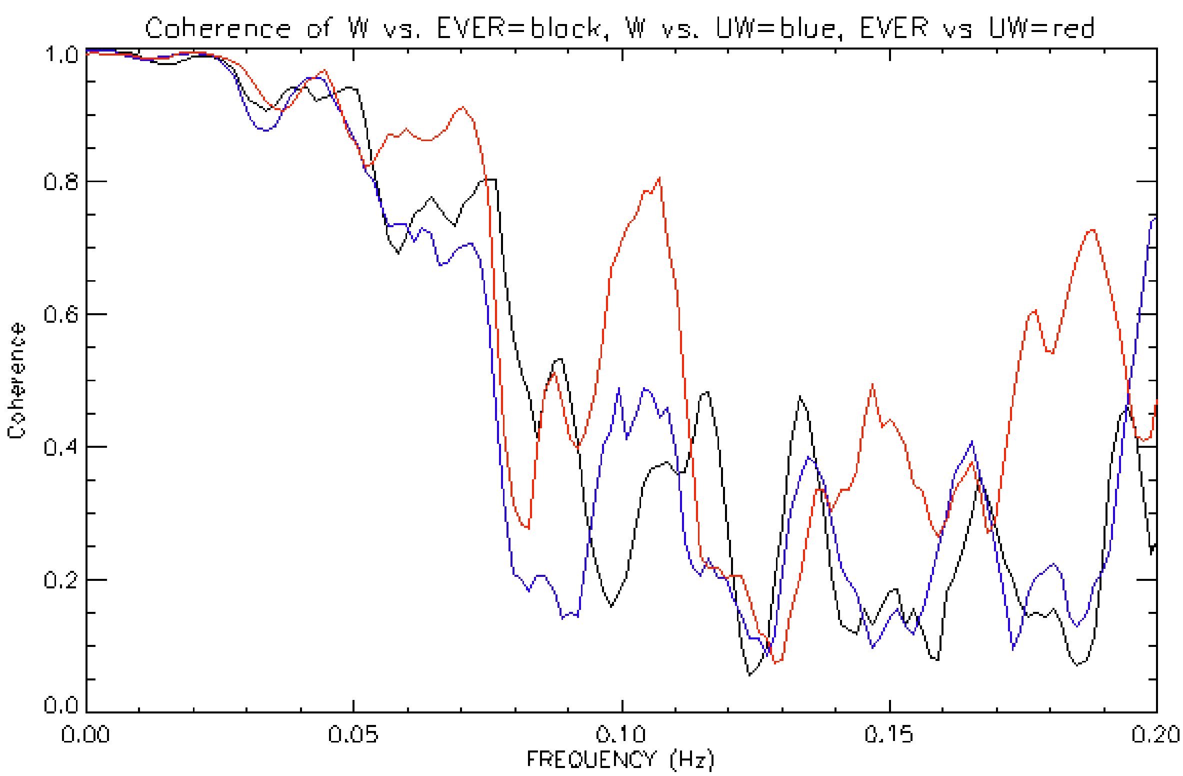


Here are the noise reduction plots:





Here is a stack of the Coherence for each pair of sensors:



<u>Conclusions:</u>
1) The roll-off above 1 Hz is due to the filtering as is the roll-off at very-low frequencies.

2) The Westlake data (blue) shows the discrete lines at 0.1, 0.2, 0.3, etc while the undersea (black) and Everglades signals do not.

3) The undersea and Everglades PSD shapes are very much alike while the undersea and Westlake PSD shapes differ significantly above 0.1 Hz.

4) There is better noise reduction when using the Everglades magnetometer for noise reduction against the undersea magnetometer (red trace is slightly below the blue trace < 0.12 Hz).

5) There is higher coherence between the Everglades vs. undersea (red trace) than the Westlake vs. underwater (blue). This explains the improved noise reduction when using the Everglades sensor as the reference.

Appendix S: ADCP Analysis for Test Files At SFOMF – March 19-23, 2015

Description:
ADCP files were acquired using a WorkHorse Broadband ADCP Version 50.40 from Teledyne RD Instruments located off the coast of Ft. Lauderdale FL in approximately 264 m water depth. Setup parameters for the data are:
"Broadband 153.6 kHz"
"Pings/Ens =" 50
"Time/Ping = 00:01.20"
"First Ensemble Date = 15/03/19"
"First Ensemble Time = 17:15:11.47"
"Ensemble Interval (s) = " 61.32
"1st Bin Range (m) = " 7.32
"Bin Size (m) =" 3.00

A total of 5506 pings were recorded over the 5 days period and stored in a file named '20150319_ADCP_LOG_UTC.txt'. Data from this binary format were translated to an ASCII format using the following procedure and parameters.
The software to view and convert the Binary ADCP data into ASCII *.txt is WinADCP. WinADCP allows the user to preview the file and Export to the ASCII files.

Output Recommended to use:: Export=>Series
WinADCP allows the user to see a preview of the file and scroll through the data with a slider bar. (best to move slider to view at end of data, to get last Ensamble# preloaded in ASCII writer fields)
Options::
FileType TXT
Bins All
Series Data selected to Export are : East(u), North(v), Vertical(w)
Ensamble to Export: First 1 , Last ####
Recommend to write the file with the same name and include '*-UVW.txt' to indicate the Exported file

Results: The data were viewed in IDL and the plots for the East, North, and Vertical velocity flow are shown in figures 1-3. Since the ADCP were set up to record 75 bins of usable data in a water depth of 264m, the last bin was 31.68m below the water surface. The plots are in-filled from near the ocean surface by extending shallowest value (bin75) up to surface.

The primary direction of water flow is to the north as seen in the Figures 1-3. An average of the entire water column could be generated showing the tidal cycles over the 5 days of recordings. This is shown in Figure 4.

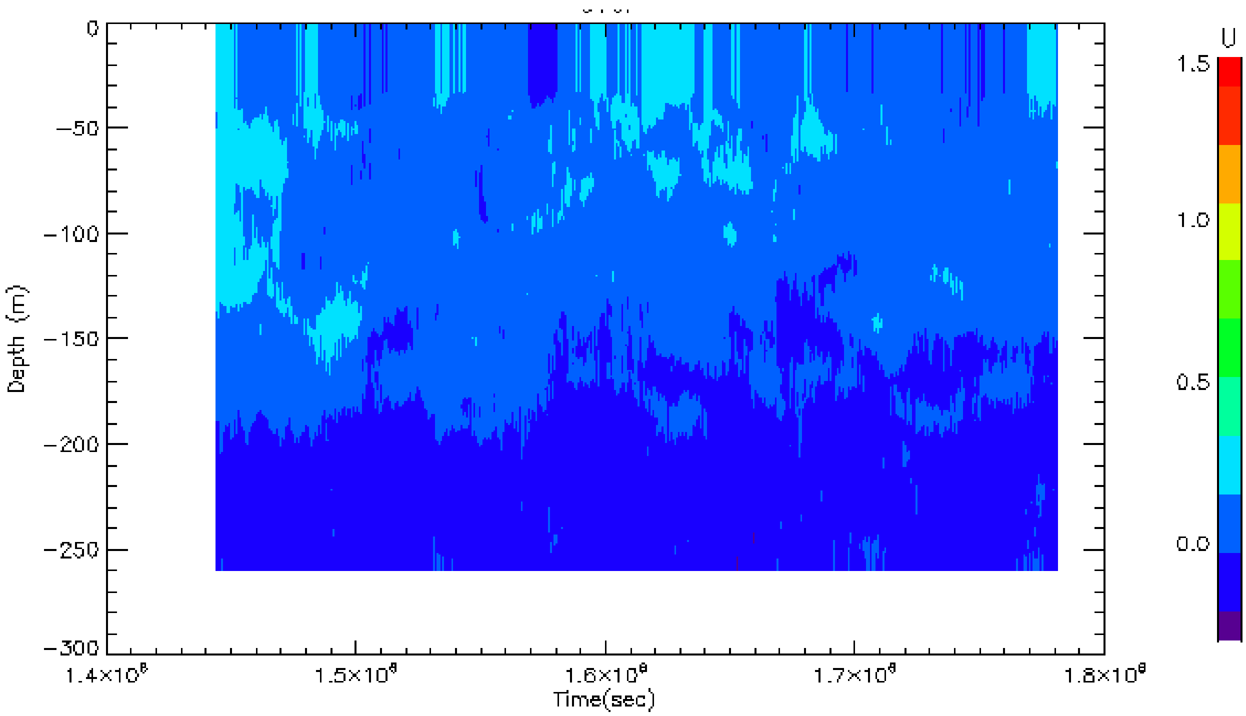


Figure 1. East velocity component.

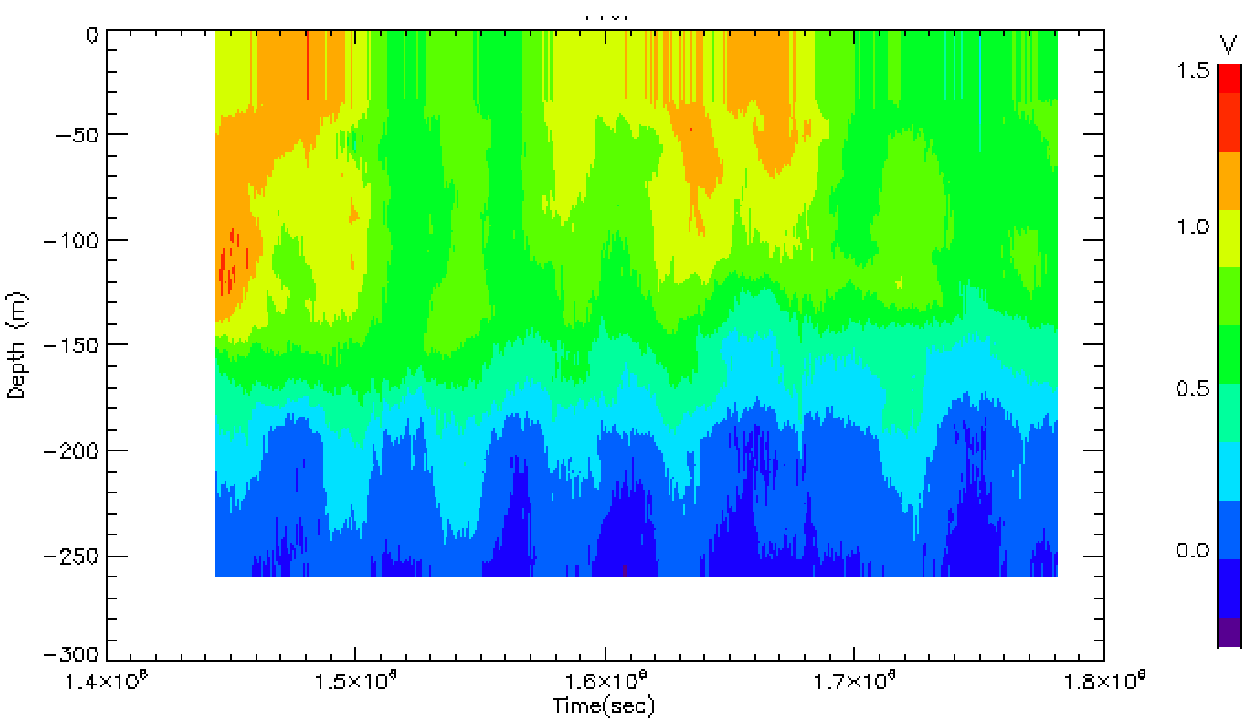


Figure 2. North velocity component.

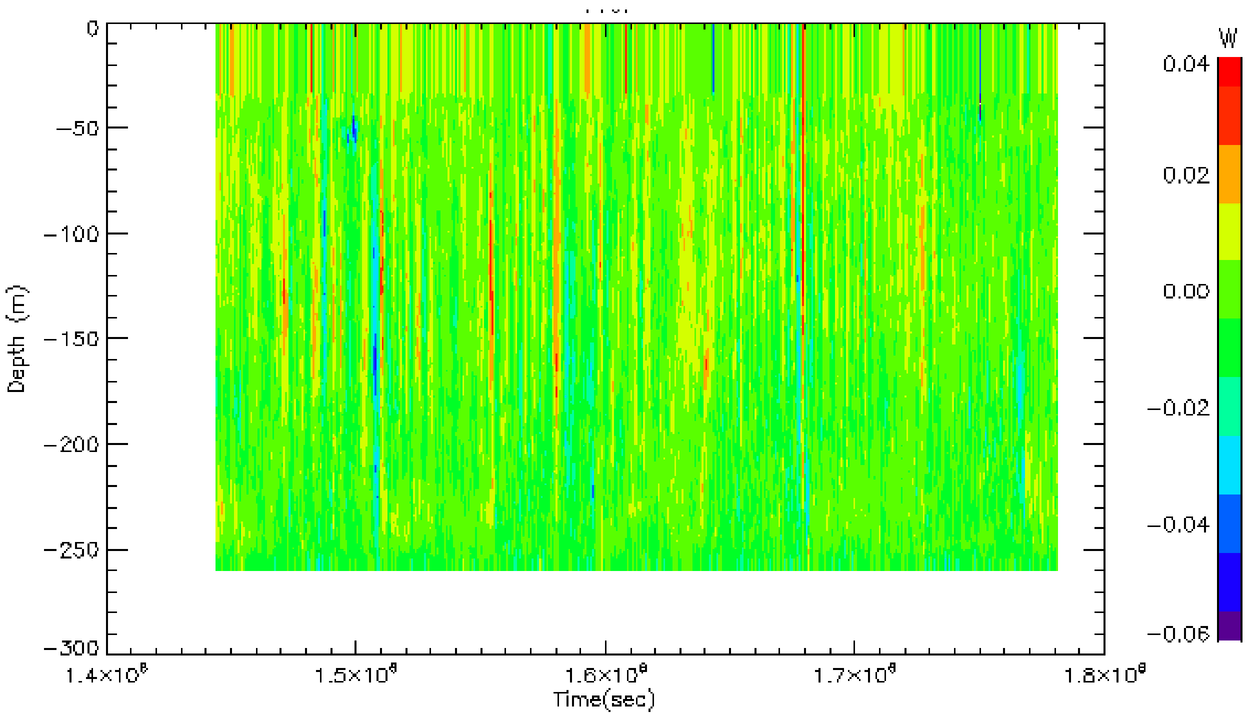


Figure 3. Vertical velocity component.

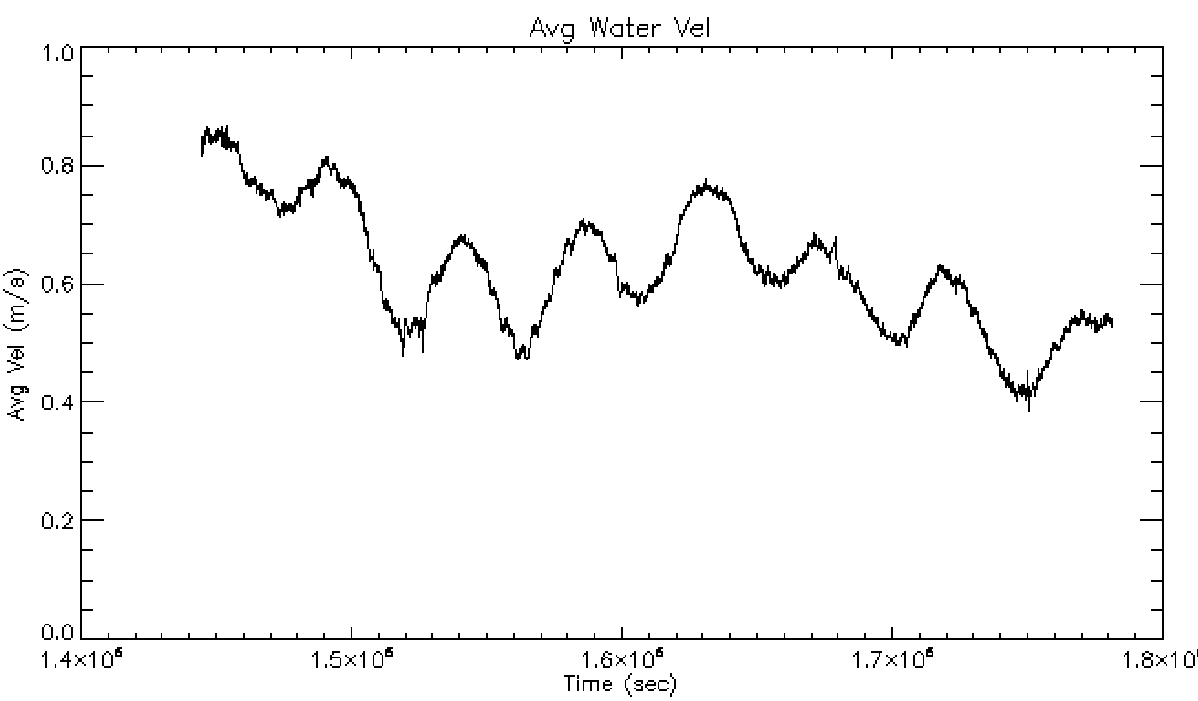


Figure 4. Average of the entire water column velocity for the recording period.

Conclusion: The ocean structure shows a significantly deeper thermocline and higher velocity structure during this portion of the year.

Appendix T: ADCP Analysis for Test Files At SFOMF – September 3-8, 2015

Description:
ADCP files were acquired using a WorkHorse Broadband ADCP Version 50.40 from Teledyne RD Instruments located off the coast of Ft. Lauderdale FL in approximately 264 m water depth. Setup parameters for the data are:
"Broadband 153.6 kHz"
"Pings/Ens =" 50
"Time/Ping = 00:01.20"
"First Ensemble Date = 15/09/03"
"First Ensemble Time = 17:55:58.82"
"Ensemble Interval (s) = " 61.32
"1st Bin Range (m) = " 7.32
"Bin Size (m) =" 3.00

A total of 6772 pings were recorded over the 6 days period and stored in a file named '20150903_ADCP_LOG_UTC.txt'. Data from this binary format were translated to an ASCII format using the following procedure and parameters.

The software to view and convert the Binary ADCP data into ASCII *.txt is WinADCP. WinADCP allows the user to preview the file and Export to the ASCII files.

Output Recommended to use: Export=>Series

WinADCP allows the user to see a preview of the file and scroll through the data with a slider bar. (best to move slider to view at end of data, to get last Ensemble# preloaded in ASCII writer fields)

Options:
FileType TXT
Bins All (since bin 75 was blank only bins 1-74 were exported)
Series Data selected to Export are : East(u), North(v), Vertical(w)
Ensemble to Export: First 1 , Last ####
Recommend to write the file with the same name and include '*-UVW.txt' to indicate the Exported file

Analysis:
The data were viewed in IDL and the plots for the East, North, and Vertical velocity flow are shown in figures 1-3. Since the ADCP were set up to record 74 bins of usable data in a water depth of 264m, the last bin was 34.68m below the water surface. The plots are in-filled from near the ocean surface by extending shallowest value (bin74) up to surface.

The primary direction of water flow is to the north as seen Figures 1-3. An average of the entire water column was generated showing the tidal cycles over the 6 days of recordings. This is shown in Figure 4.

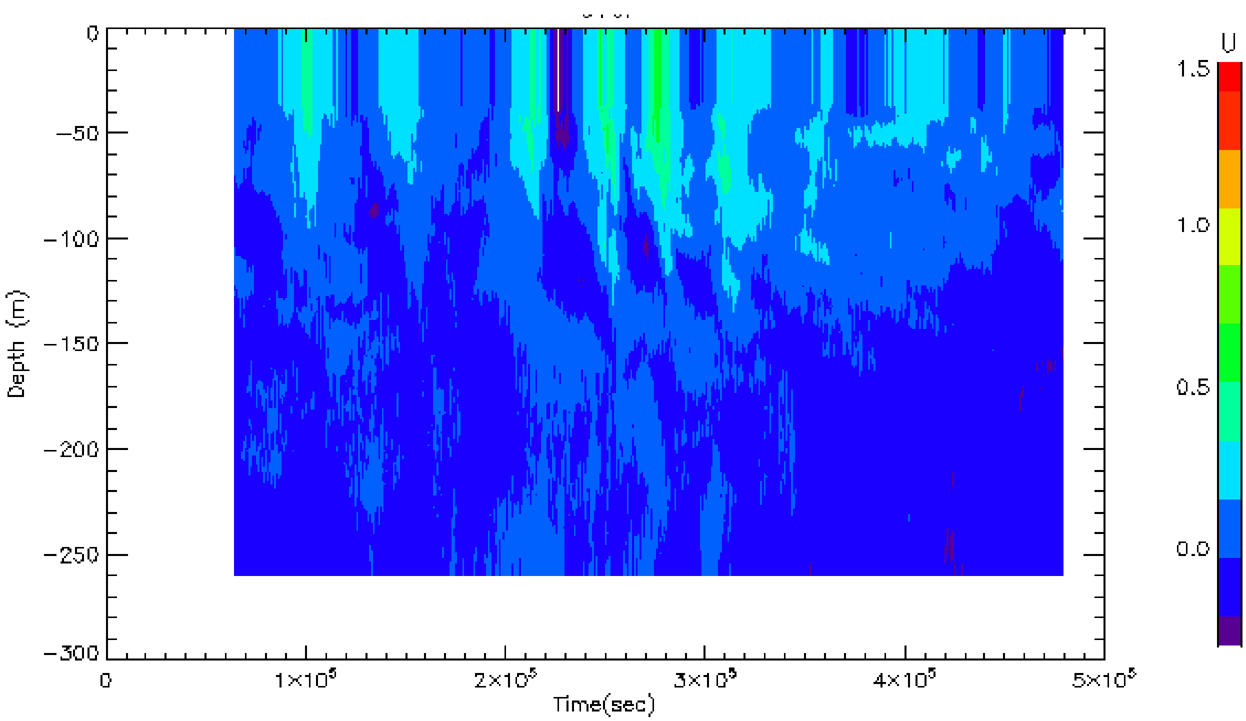


Figure 1. East water velocity measured from the bottom.

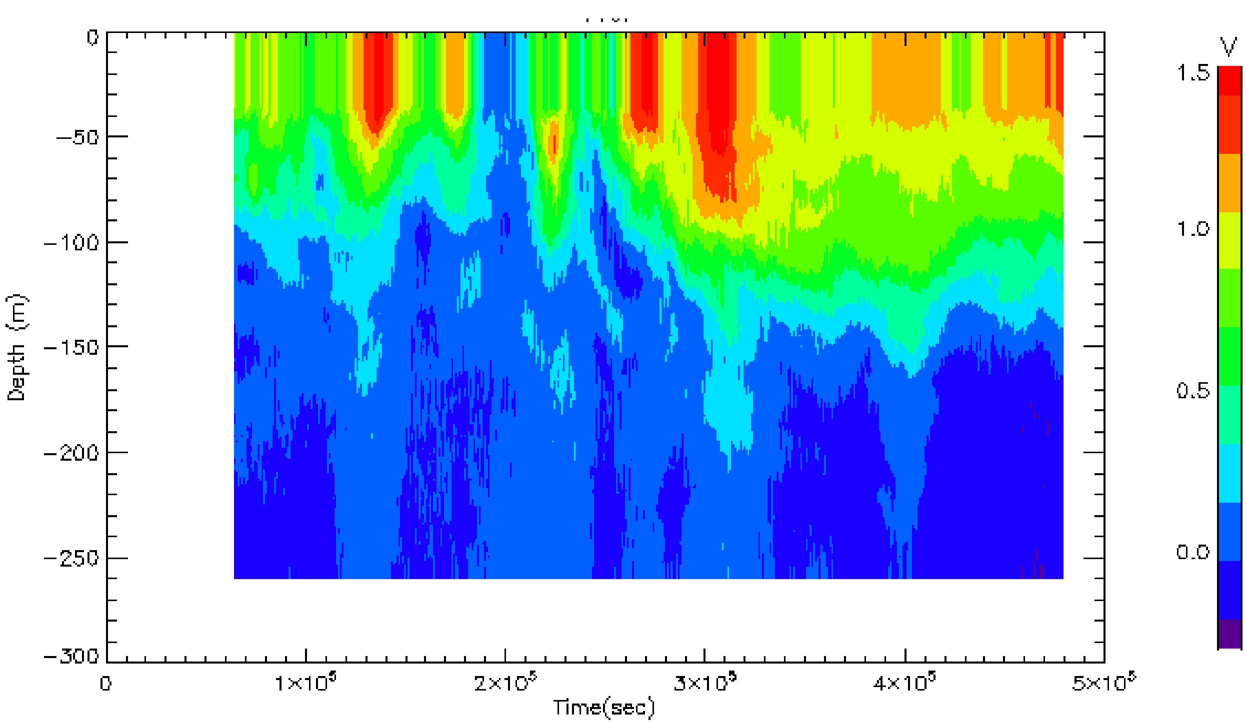


Figure 2. North water velocity measured from the bottom.

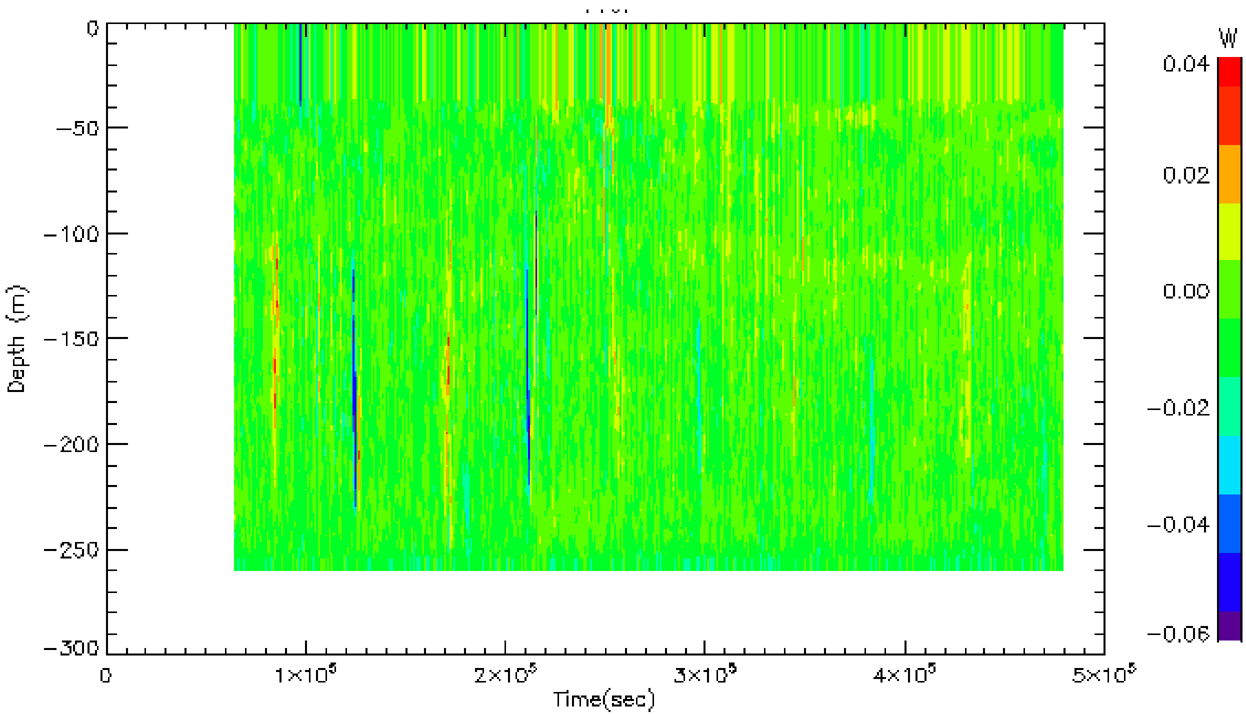


Figure 3. Vertical (up+) water velocity measured from the bottom.

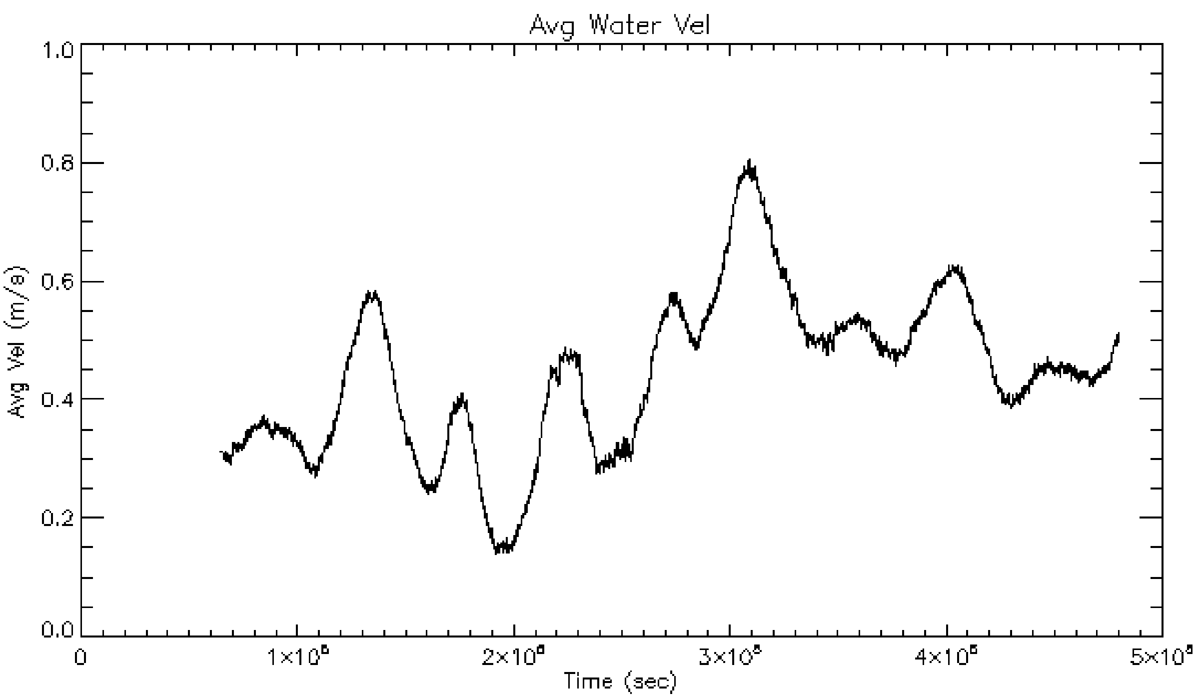


Figure 4. Average of the entire water column velocity for the recording period.

<u>Analysis of Sept 7 ADCP to explain anomalies in the magnetic data:</u>

Complimentary magnetometer files were recorded during this same period to evaluate the data acquisition system. A significant amount of the magnetometer analysis was done for Sept 7 and some unusual features were observed. Figures 5-7 focus on the Sept 7 time frame for the ADCP data to look for any obvious effect that the oceanography could have on the magnetic sensor equipment.

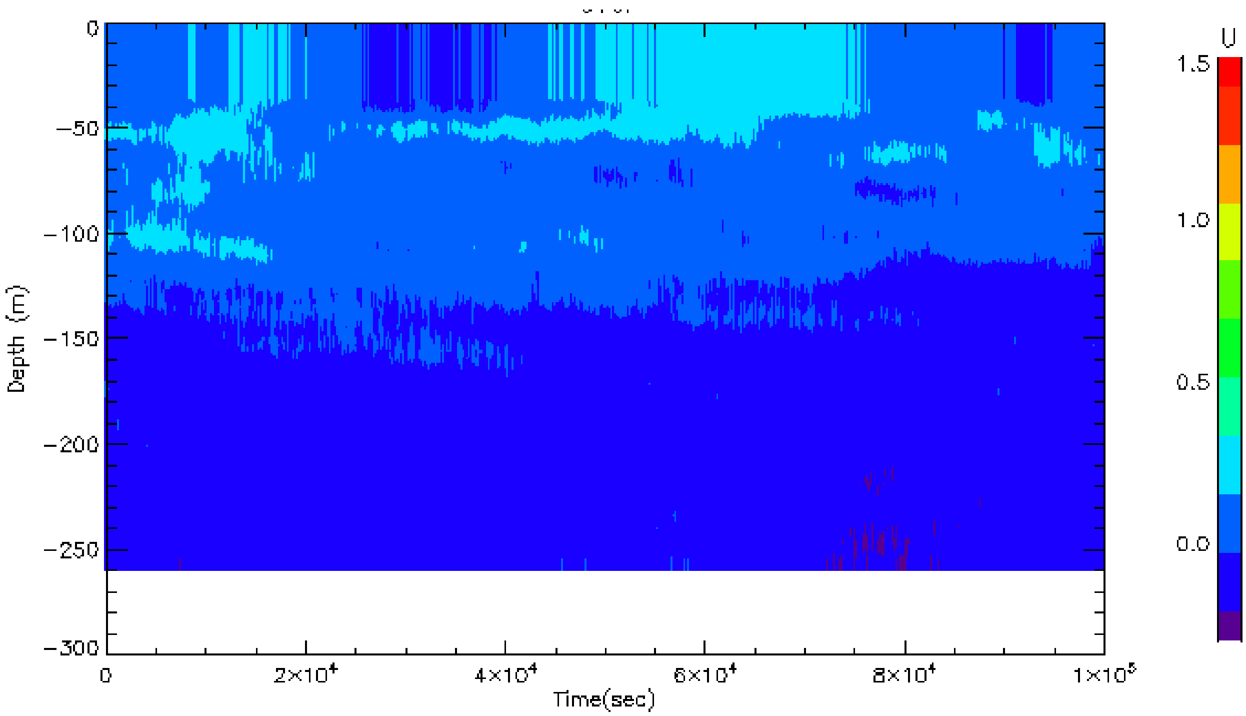


Figure 5. East water velocity from the ADCP site zoomed to the day Sept 7.

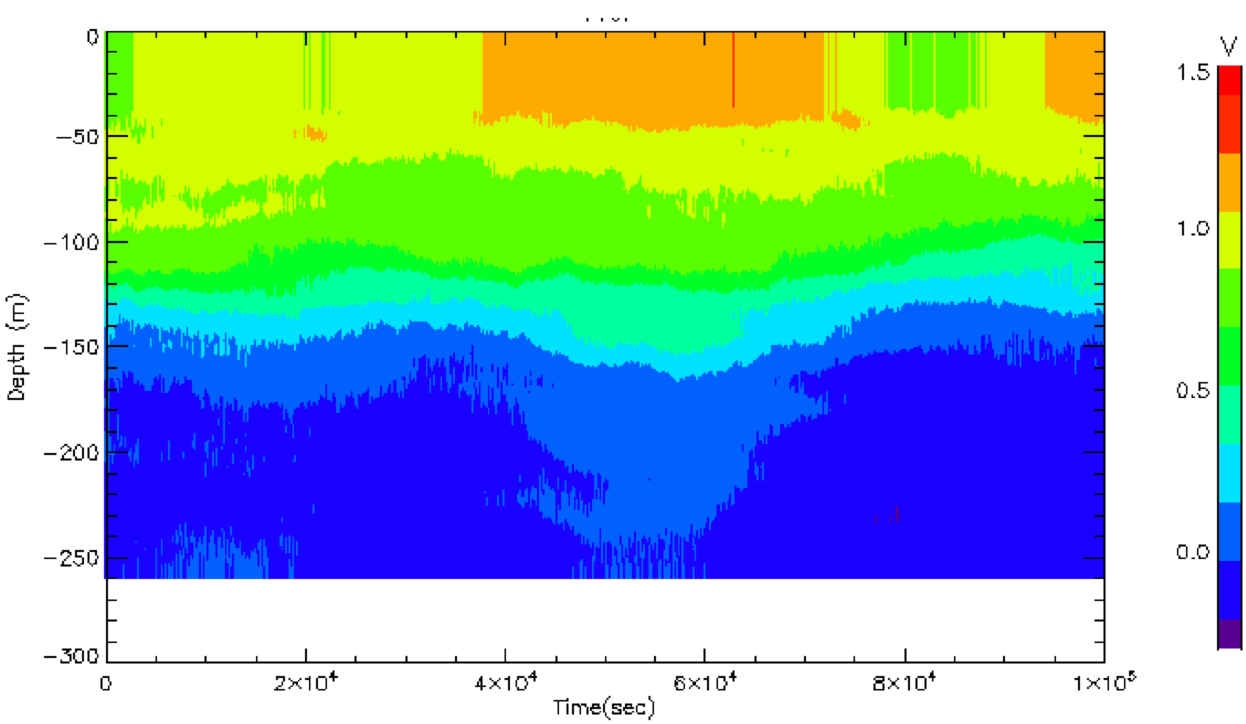


Figure 6. North water velocity from the ADCP site zoomed to the day Sept 7.

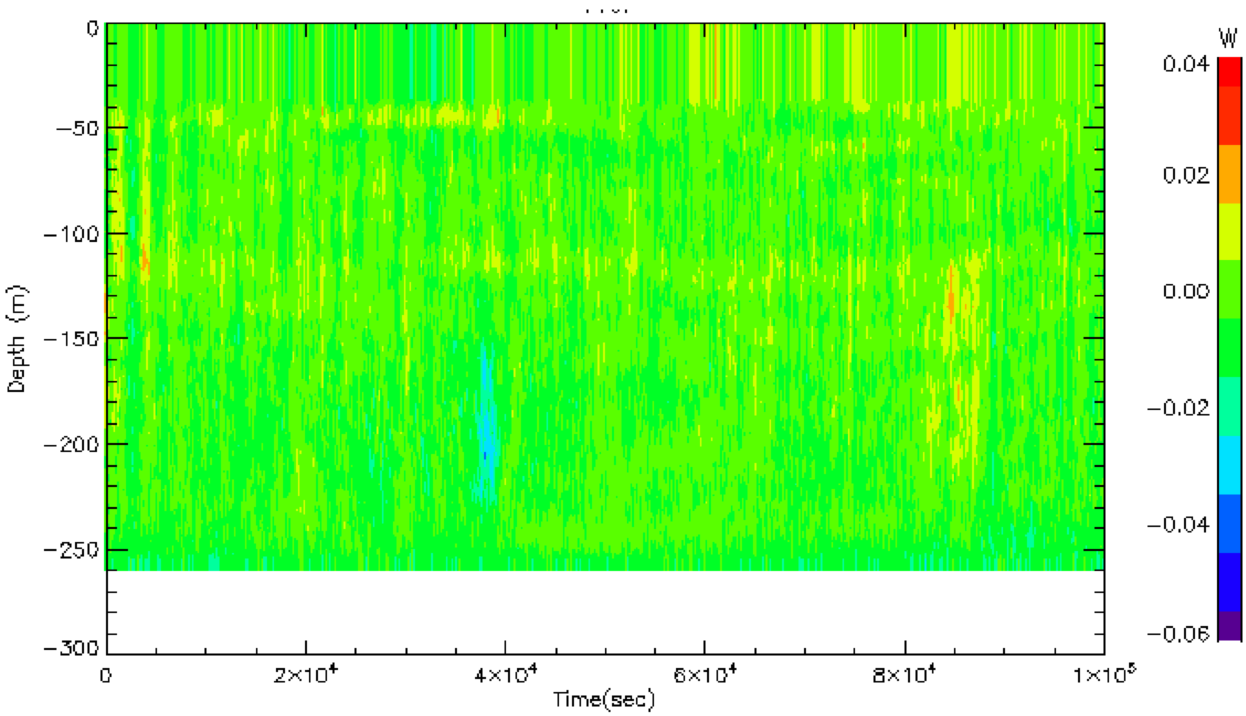


Figure 7. Vertical water velocity from the ADCP site zoomed to the day Sept 7

<u>Conclusion:</u> Examination of the September 7 ADCP velocities indicates that the velocities near the bottom are not sufficient to move the magnetometer platform and sensor. The north velocity does show a significant deviation during the day around Time second 50000, but this is a long term excursion of the velocities not a short term feature. As a result, there are no significant short-term features that could create any anomalous excursions on the undersea magnetic sensor.

Distribution List

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